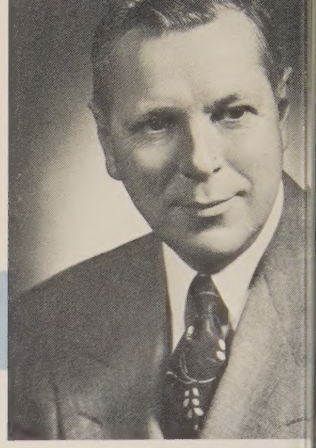
GENERAL MOTORS

Engineering JOURNAL

Volume 1 September-October 1954 Number 8



On Adapting Technical Knowledge

The ENGINEER is man's ambassador to nature—and diplomatic relations continue to improve from year to year. Nature, though bountiful, does not easily exchange her elements and energies to the persuasive effect of the many types of engineering connected, for example, with the transformation of ore into the starting motor of a 1954 automobile.

To be a good ambassador, the engineer needs to adapt fundamental technical knowledge to tasks as they exist *today*. In today's industrial world of group effort, the demands on the engineer go far beyond a skill in designing parts and components that must satisfy ever-increasing customer demands of function, durability, and appearance. The demand for technical improvements in the manufacturing facilities and processes have become as important as those in the product itself. Take the case of a typical modern transfer machine, 150 feet long, weighing hundreds of tons, and performing 19 separate operations on an engine block. Such a machine does not appear in a plant without a great amount of technical planning involving plant layout, materials handling, and manufacturing methods and processes—to overlook entirely the development of the machine itself.

This machine is now used in an engine plant having two 480-foot-long assembly lines which, at capacity, each turn out two engines a minute. The engine making task is broken into scores of integrated assembly line operations enabling simultaneous work by hundreds of men. Muscle power is reduced tremendously by machines. Two and one-half miles of conveyors bring materials to the assembly points and, while the engine weighs more than 500 pounds, no worker normally lifts any component part weighing more than 10 pounds.

Examples of technical advancements in the product and the methods and processes by which the product is manufactured are legion. Each one, however, points to the ability of engineering thinkers to adapt their knowledge to an existing job requirement. Technology, on the whole, has made immense gains in the man-machine relationship during the past century. Now, man's muscles contribute but four per cent of the power needed in production. A hundred years ago they contributed 15 per cent. Machines, meanwhile, now provide 84 per cent, against only 5 per cent a century ago. Animal power has been reduced from 80 per cent to 12 per cent during the same period. This reduction of man's effort by a factor of nearly four symbolizes a trend toward substituting man's ingenuity for man's muscles, and the ultimate beneficiary is the customer —who gets more for less.

In the automotive industry particularly, the trend of making a better product while improving the manufacturing methods and processes used to produce it is an ever increasing one. Improvements on individual components and parts of the vehicle await only an ambassador who can adapt technical knowledge to gain from nature a better metal, a better mechanical advantage, or whatever the next step forward may require. More important, major changes as radical as the automatic transmission will come just as certainly as there are engineers at work and in training who can cinch and pry upward the progress curve. Likewise, other engineers will find their challenge in improving, maintaining, and supervising the electrical, mechanical, and hydraulic machines to make the components and in the equally important tasks of developing methods and processes for their use.

In sum, the engineer's contribution is made through his ability to discover the principles and materials which nature has had available since the beginning of time and to adapt fundamental knowledge to new tasks.

L. C. Goad,
Executive Vice President

THE COVER

Diesel Equipment Division contributes this, the seventh of a cover series portraying transportation developments. Senior Commercial Artist Melson J. Wachsman's pressure-fed hydraulic valve lifter symbolizes the importance of the engineering effort which is applied even to small components of today's vehicle and aircraft engines. In this case the engineer's task is to design for volume production and retain all of the performance characteristics which hydraulic valve lifters fulfill as an integral part of the valve train. The factory scene in the background shows an automatic screw machine department which produces plungers for hydraulic valve lifters.

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GENERAL MOTORS

Engineering JOURNAL

Vol. 1 September - October 1954 No. 8

Published with the help of General Motors engineers everywhere

The GENERAL MOTORS ENGINEERING JOURNAL is published every other month by the Educational Relations Section of the Department of Public Relations, General Motors Corporation, and is intended primarily as a medium for presenting to the field of engineering education the results of General Motors research and engineering developments both in the product and production fields.

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The Engineering Organization and Facilities of a General Motors Division

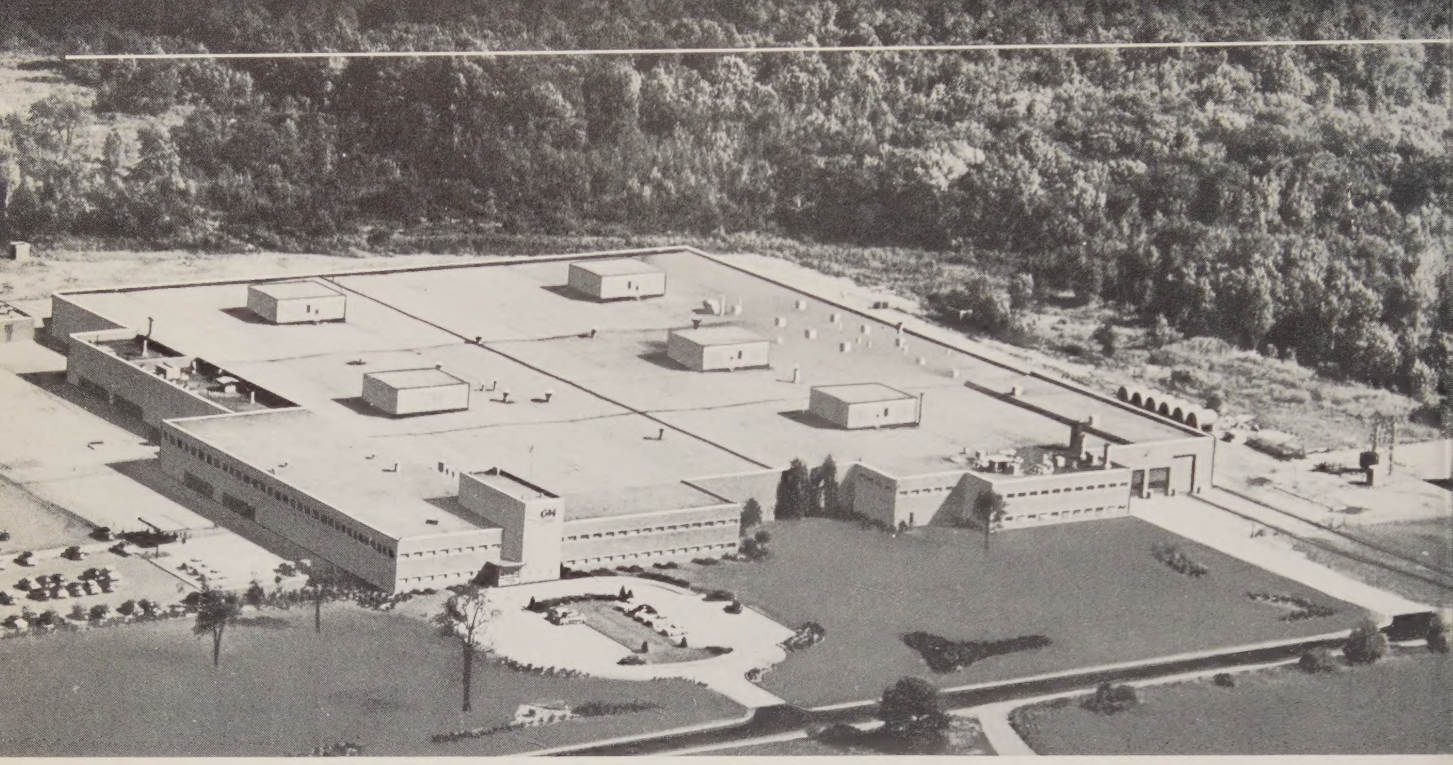


Fig. 1—The Diesel Equipment Division plant at Grand Rapids, Michigan, was built in 1946 and expanded in 1950. The engineering area is located on the second floor (left foreground).

The total engineering of a complex product—such as an aircraft, automotive, or Diesel engine—is no better than the engineering of its individual parts. Diesel Equipment Division in its first 10 years of existence has developed an engineering organization which specializes in engine parts manufactured by the millions for use in GM and other engines. As in all technical organizations, the engineers' main function is to make maximum use of available man power and materials. The Engineering Department organization is quite conventional. Some of the unconventional problems which constantly require solutions deal with the metallurgy and the hydraulic pressures of the Division's products.

DIESEL EQUIPMENT DIVISION of Grand Rapids, Michigan, one of the newest of the General Motors Divisions was born because of a World War II need for greater production of a single Diesel-engine item. By the end of the war the Division's engineering personnel had led the new organization into readiness for the manufacture of many more new engine components for automotive, aircraft, and Diesel engines—and this expansion in production diversity continues today. Thus, Diesel Equipment Division has become essentially a volume subcontractor of certain engine components, and the largest users are the GM car-production Divisions.

The Division was organized in 1944 when the equipment for manufacturing Diesel fuel injectors was transferred from Detroit to Grand Rapids. The equipment transfer and establishment of a new GM Division especially to make fuel injectors were due, in part, to a war-time unbalance of available labor. There was a severe labor shortage in Detroit but somewhat of an excess in the Grand Rapids area. During the post-war reconversion period, expansion continued so that the new Division soon outgrew its quarters. Fig. 1 shows the plant as it is today, a modern air-conditioned structure.

During the Division's first year the Engineering Department was primarily a production-engineering group handling normal daily problems concerning production tolerances, print variations, quality of the product, and many other items. In 1945 the Engineering Department established a Development Group to improve the existing product (fuel injectors) and to develop new products. As new products were put into production, the Engineering Department and Development Group grew both in personnel and facilities—a growth which is still continuing.

Organizations such as Diesel Equipment Division are suppliers or subcontractors possessing complete engineering facilities which enable them to develop new products. This offers an advantage in the development of specialized items since it allows the engineering groups to concentrate on these items without having to cover too wide a range. It is necessary, however, for the engineer to know the complete workings of the end product in order to accomplish his job satisfactorily.

Product Growth

While production continued on fuel injectors, the first new product developed was an interchangeable fuel nozzle for gas-turbine or jet engines. This was a new

By WILLIAM J. PURCHAS, JR.
Diesel Equipment Division

A chief engineer relates how a GM Division sprang from a fuel injector

field for the Division. The original fuel-nozzle system employed selected sets of nozzles which had to be retained in sets. This was a complicated system necessitating extra time to change the complete set even though only one nozzle was defective. The need for an interchangeable nozzle was, therefore, evident. The first type of nozzle designed, called a *simplex*, covered the fuel-flow range satisfactorily and could be changed one at a time, similar to a spark plug. As demands mounted for fuel-flow increases, it became necessary to design duplex nozzles to cover the wider flow range. This has been accomplished, but the still higher requirements constantly being requested continue to call upon the engineers' agility to solve the new problems which arise.

The next new product to be developed was the hydraulic valve lifter for passenger-car engines. This unit had to provide automatic lash adjustment and had to be economically priced. As various hydraulic valve-lifter assemblies were developed and put into production, the requirements changed and problems encountered in service had to be overcome. Lash adjusters for Diesel engines also were added to the new-product list. These units differed from the hydraulic valve lifters in that they automatically adjusted the lash but did not run in contact with the camshaft.

Not all of the new products put into production originate at the Division. Some products are put into production from drawings supplied by customers. In such cases, the Engineering Department sets up groups to carry on a ceaseless program for an improved product, meanwhile working closely with the customers' engineers. Typical products of this nature produced at Diesel Equipment are piston rings, exhaust valves, hydraulic propeller controls, and automatic hydraulic gas valves.

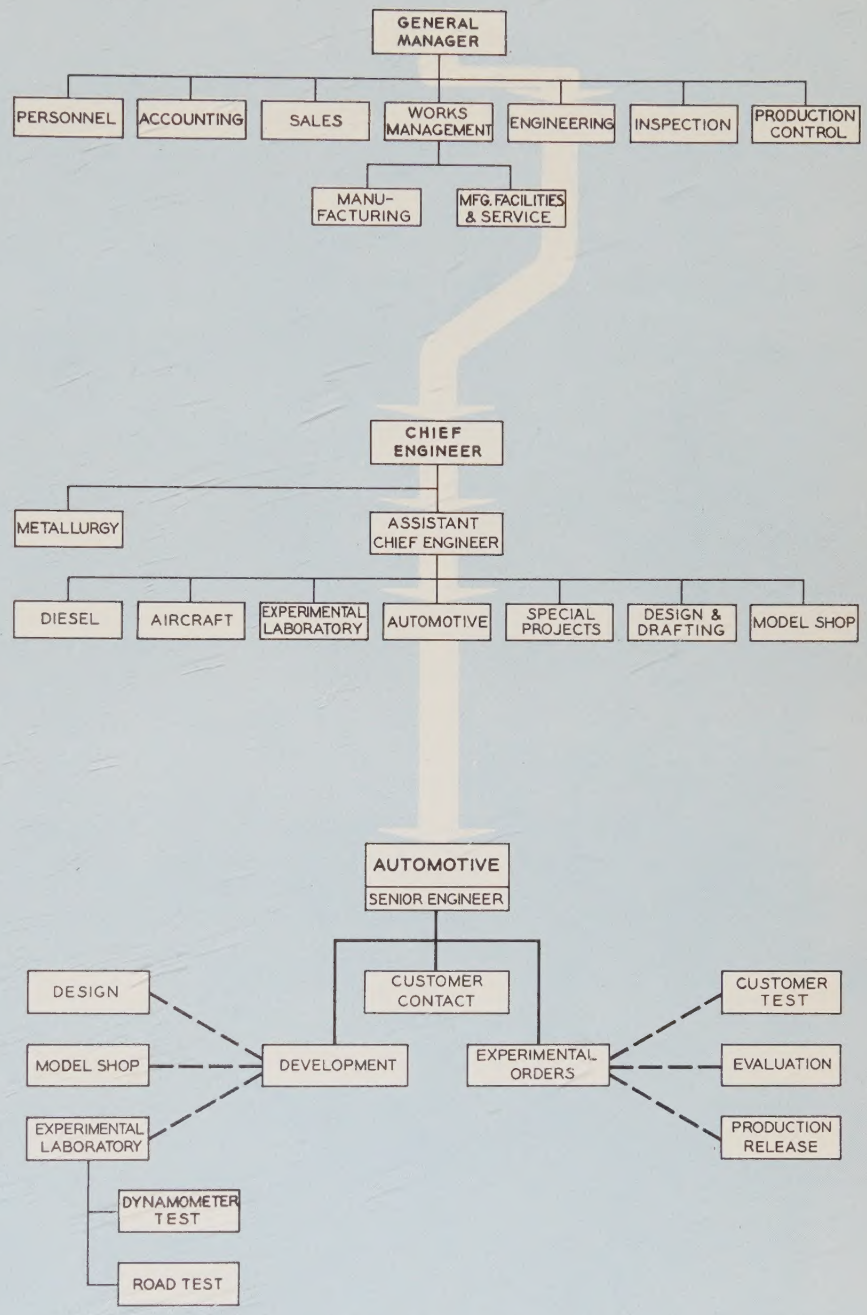


Fig. 2—The Engineering Department, headed by a chief engineer, is one of the Division's operating Departments (top). This Department's organization is shown in the center. The functions of the Automotive Group, typical of three other product groups in the Department, are shown at bottom.

Along with the above-mentioned products, a group of engineering-development items are being worked on in anticipation of the future needs of GM car-producing Divisions and other engine manufacturers. Some of these items, however, are not being used at present—nor is the time right for their use—but they must be engineered in readiness for anticipated requirements.

Fig. 3—Section of drafting room staffed with men performing the important function of product design. Ideas and improvements essential to continuing progress are worked out on paper by the Design and Drafting Group.

Engineering Personnel

The Engineering Department is made up of eight groups, four being product-engineering groups which cover the Diesel, aircraft, automotive-engine equipment, and special-project areas, and the other four being service groups (Fig. 2).

The product-engineering group for each major area is headed by a senior engineer and staffed with project and junior engineers. It is each group's responsibility to follow two paths: to develop new designs for future use and to improve the present design. This means that the senior engineer is also the sales engineer for his particular product. He contacts the customer to obtain the necessary specifications and requirements; he also directs the new-development projects and is responsible for the work of the production engineers in improving the existing products in his area. It has been found that by having each product-engineering group responsible not only for new product developments but for existing products as well, engineers are more conscious of what they develop for production since they maintain a continuing association with existing products. Engineers who do the original developing and testing, therefore, are held responsible from the inception of a product through tooling for production—and mistakes are more likely to be avoided.

Functions of the Product-Engineering Groups

Each product-engineering group consists of specialist engineers who design and develop product assemblies for mass production. The four product-engineering groups must continually progress in improving the product so as to give the customer the best quality and to be able to act as advisors on customers' problems. The majority of these products undergo complete functional tests before they can be shipped to the customer. It is up to each product-engineering group to set up the specifications to which the Manufacturing and Inspection Departments work.

The Design and Drafting Group works with all the product-engineering groups and is responsible for designs, drawings, records, calculations, blueprints, and many other functions. It is headed by a supervisor who is a graduate engineer with the same relative classification as the senior engineer. His Group consists of designers, layout men, checkers, detailers, specifications man, and miscellaneous machine operators for the blueprint facility. Too often, young engineers fail to realize the importance of this type of work and pass up excellent chances for advancement (Fig. 3).

The Metallurgy Group also works with all product-engineering groups and is headed by a chief metallurgist who has a dual-functioning staff consisting of metallurgists and chemists. One part of the staff works with the product-engineering groups to obtain the best in

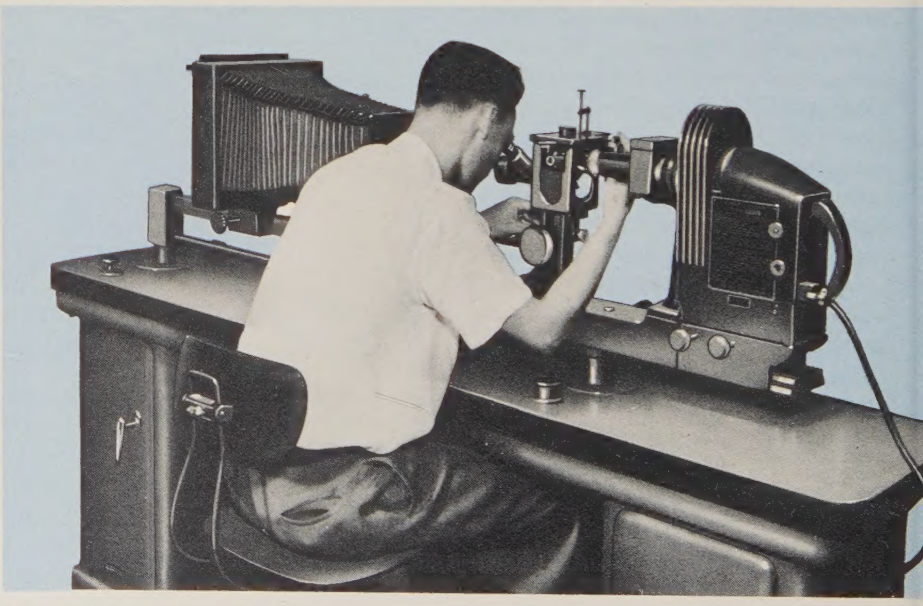


Fig. 4—Metallographer checking the microstructure of a sample of bar steel for grain size, cleanliness, and other factors affecting machineability. The metalloscope is typical of many other types of devices for analyzing the Division's material problems.

Fig. 5—In the tool-room section of the Model Shop, experienced craftsmen work with modern equipment to fabricate products for experimental test purposes.

materials and heat treatment for a given part. Work is directed toward new and better materials as well as toward the use of forgings, castings, and other means of fabrication to see that the proper specifications are established for the jobs. The second element of the Metallurgy Group controls the quality of steel, cast iron, or any other material that has to be checked before being used for production. Specifications to which materials are heat treated also are set up. Other important items considered are the oils used by various departments in manufacturing and oil reclaiming. Finally, standards are set for magnifluxing parts, recommendations are made for equipment to be bought for the Production Heat Treatment Department, and various other related duties are performed.

The Metallurgy Group must be very flexible as it covers many items involving a number of other departments and plays an important role in maintaining the quality of the product. Fig. 4 shows a metallurgist checking the quality of a steel sample under high magnification.

It is imperative that the various product-engineering groups, the Design and Drafting Group, and the Metallurgy Group possess an excellent knowledge of the manufacturing methods and processing techniques of the plant. In this way, these Groups can more surely fit the new product into existing Divisional operations. It is also important that these Groups work closely with the processing groups to minimize the changes after the product is put into production.

Operations of the Service Groups

The Experimental Laboratory Group maintains facilities for engine testing and functional bench testing as well as acting as a service group for the four product-engineering groups. This particular service group has a supervisor and is staffed with project mechanics, dynamometer-test operators, flow operators, instrumentation men, and is supplemented by a Photographic Section. The responsibility of this service group is to evaluate new designs for both functional and durability characteristics. The evaluation pattern to be followed is laid out by the product-engineering group which requests the test.

Last, but not least, of these service groups is the Model Shop (Fig. 5). It is staffed by men who are experts in their

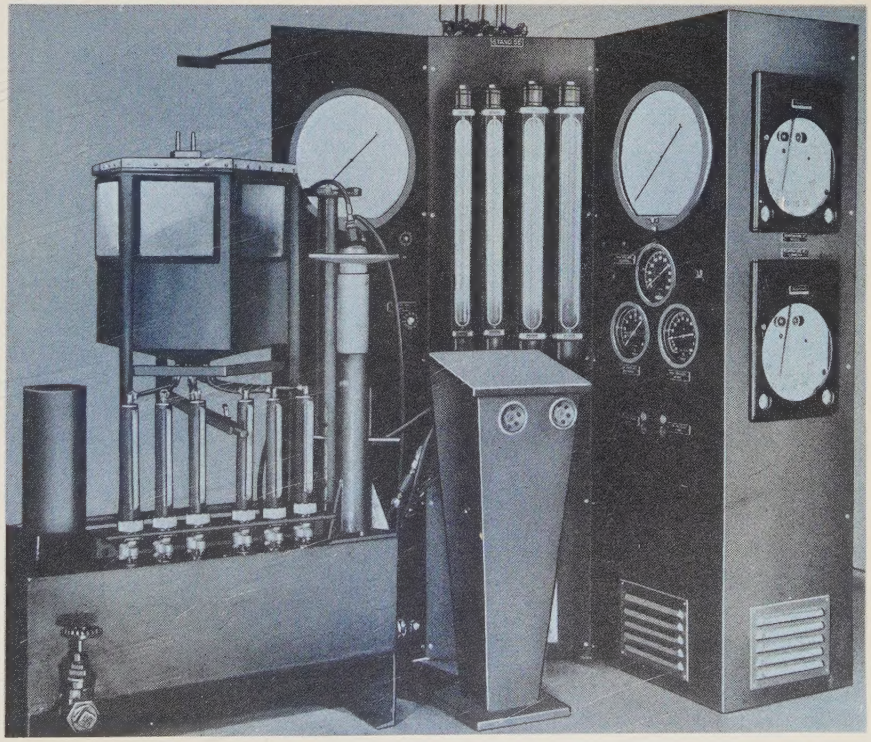


Fig. 6—Nozzle test stand was designed and developed by Diesel Equipment Division for checking nozzle characteristics such as flow rate, flow pattern, and atomization. Important instrumentation includes flow meters in center, sensitive pressure gages on either side, and distribution (patternation) chamber and burettes on the left. Pressure-adjusting-valve knobs appear in the center and temperature dials on the right.

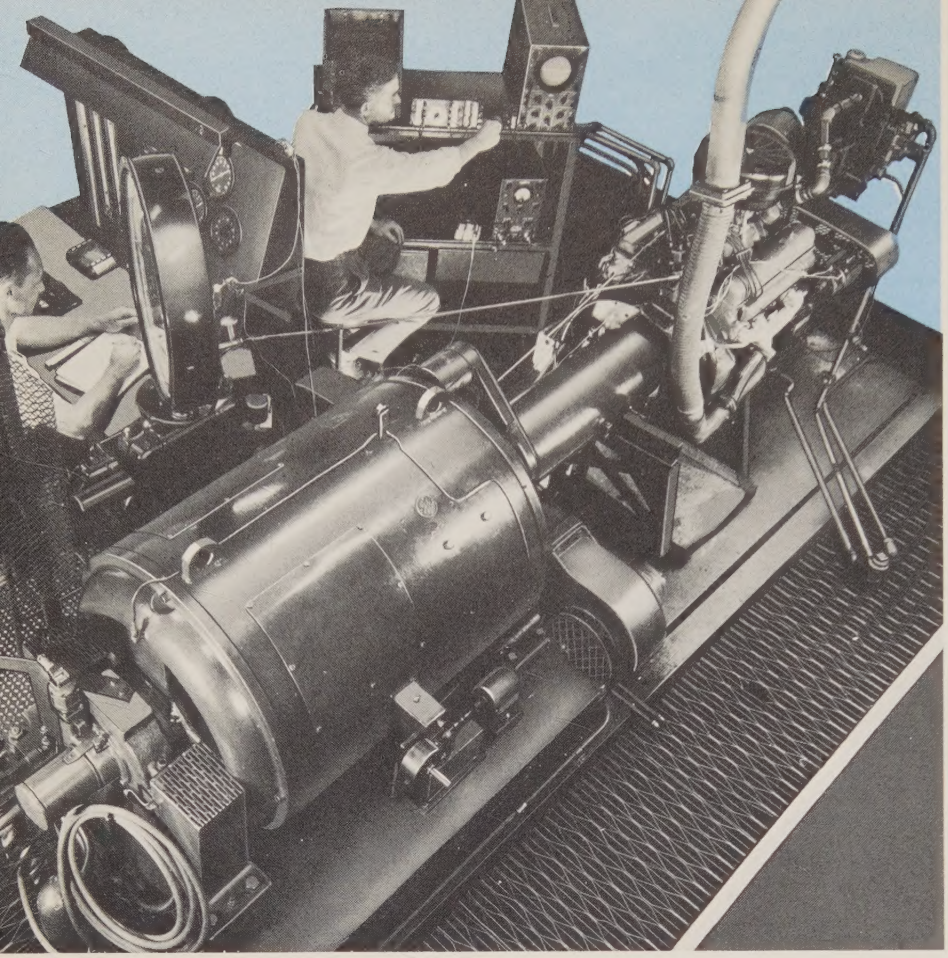


Fig. 7—Part of automotive-engine analysis is made with electronic instrumentation. Power is measured by a dynamometer while fuel consumption and other engine data are taken by a technician seated at the control panel (left). These control panels were designed and constructed at Diesel Equipment Division.

respective fields for machining parts needed by the Model-Shop foreman. All experimental parts are made in this area and it is of utmost importance that they be made exactly to the blueprint in order to eliminate faulty results when tested by the Experimental Laboratory Group.

When the product is submitted to the customer, the engineering is as complete as possible and yet the task may be just beginning because the customer often requests specific details to meet his particular application. At this time, the product-engineering group involved works directly with the customers' engineers and, after a series of changes and more testing, a satisfactory product is obtained.

Another type of problem arises with the suppliers who furnish special items. This requires direct contact between their engineers and Diesel Equipment's product engineers and metallurgists in order to meet the Division's requirements. For most small suppliers, the Division's engineers set up specifications and do the testing as these suppliers usually do not have facilities for such work.

Special Instrumentation

With every new product comes the problem of testing to best evaluate its end use. In some cases, a separate program is required to develop test equipment for this purpose and, at times, the test equipment may become more complicated than the product. With products that change continually, such as aircraft parts, the test equipment must be improved along with the product.

Fig. 6 shows a jet-nozzle flow stand that was engineered by the product-engineering group which developed the nozzle. The very best in pressure gages, flow meters, patternators, and temperature controls were designed into this stand to give the required accuracy. The flowmeters measure precisely the flow of fuel while the patternator measures the distribution of fuel to obtain an even spray pattern and uniform spray angle.

Fig. 7 shows a typical dynamometer-test room where various assemblies are tested on the engines for which they were designed. As can be seen, very elaborate electronic instruments are required to engineer the assembly properly. Both gasoline and Diesel engines are used in the laboratory and in the road-test vehicles.

Many significant lessons are learned during the testing procedure. Of particular value is the knowledge gained about available materials in which new developments occur regularly. The metallurgists and chemists continually find new combinations of materials that are far superior to those currently available. Each time this happens it changes considerably many present-day evaluations. As a result, many Diesel Equipment Division product improvements can be attributed to this testing function, for without it parts for higher power and higher temperatures could not be produced.

Another example of an application of new developments in instrumentation is in the study of hydraulic action—one of the most difficult areas in which to make predictions. Flows through various-sized orifices under extreme pressures make the successful design of such parts as fuel injectors and jet nozzles dependent more upon the experiences of the engineer than is the case with other devices. Among the instruments that have contributed importantly to the evaluation of hydraulics are the electronic types. The rapid means of transferring pressure waves and motion cycles to a recording device has helped the engineer study and visualize what is actually taking place whereas, before electronic instruments were used, the work was largely a matter of approximation. These same types of instruments are also used for recording temperatures and many other kinds of data that are essential to develop a satisfactory product.

Summary

As Diesel Equipment Division completes 10 years of operation, opportunity for the engineer remains unlimited. With new products come more and better jobs for the engineer as his imagination and vision are applied. Much has been said about the development of the product but even more emphasis is placed on the constant development of the engineer. His growth is the fundamental element of progress on which, subsequently, the survival of the organization depends.

How a Comparative Weight Analysis of Aircraft Actuators Aids Designers in Choosing the Most Efficient Type

By ROBERT C. TRESEDER and HOWARD M. GEYER

Aeroproducts Operations
Allison Division

Several thousand actuators are used to assist the pilot in flying a modern multi-engine military aircraft. Choosing the proper actuator for each job involves a variety of factors. A study has shown that definite trends can be predicted that help the aircraft-design engineer make his choice. Both the generation and storage of the power fluid influence the selection of the type of actuator to be used. Often, a combination of hydraulic, pneumatic, and electric actuators may be used on one aircraft.

For power to move aircraft structures: three choices in design

THE work that must be expended to actuate adjustable flight surfaces and to operate the landing gear, bomb doors, and other movable structures on aircraft often exceeds pilot capabilities. At the same time, the increase in physical size of aircraft during recent years has all but ruled out mechanical transmission systems. To provide for power amplification and to eliminate mechanical links, the aircraft-design engineer uses a multitude of remotely controlled actuating devices, known more simply in the aircraft industry as *actuators*.

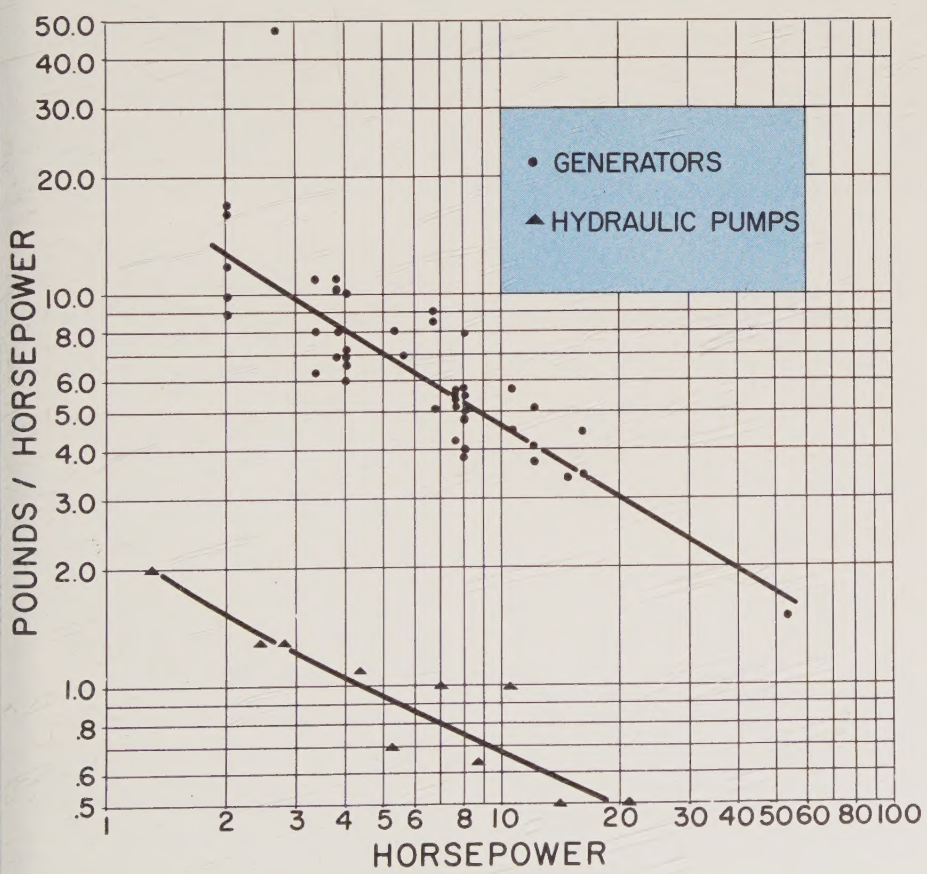


Fig. 1—Logarithmic plotting of specific weight versus horsepower of electric generators and hydraulic pumps, based on manufacturers' data, shows a straight-line relationship. The trend in actuators toward reduced specific weight as horsepower is increased is apparent. In the case of electric generators, however, the improvements obtained in larger sizes are not due to size alone; many recent design advances also are reflected in such gains.

The work of an actuator can vary from a few hundredths of a horsepower, in the case of a cowl-flap actuator, to 10 hp or 20 hp in the case of a large landing-gear actuator or a flight-surface actuator for a high-speed airplane.

When comparing the three types of power-transmission fluids—electric, hydraulic, and pneumatic—and the type of generation, transmission, and actuation that may be used, a multitude of variables at once becomes apparent. To simplify the presentation in this paper, one very controversial point of comparison is avoided entirely. That point is reliability. Improvements are being made so rapidly in each of the power-transmission systems that statements made today on reliability would be out-of-date and possibly incorrect in a few months.

The comparison of power-transmission systems is made, therefore, on the basis of weight, size, and overall efficiency. It is appropriate to examine (a) the generation of the power, (b) the storage of the power, (c) the transmission of the power, and (d) the utilization of the power by the actuator.

Power Generation

A-c and d-c Generators

Electric generators for aircraft have become fairly well standardized over the past few years and it is possible to obtain from the manufacturers of such equipment rather consistent data on both weight and efficiency. Fig. 1 shows a plot of specific weight—that is, pounds per horsepower—versus horsepower for

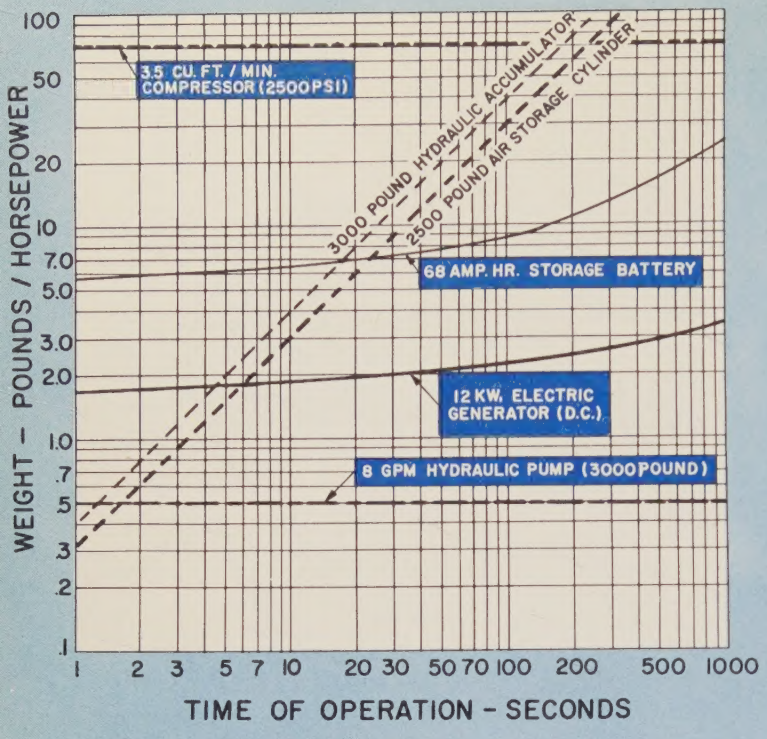


Fig. 2—Comparison of power sources, including storage means, showing specific weights plotted against operating time of the actuator. This chart is useful to the aircraft-design engineer in a number of ways. For example, it shows that the storage battery is heavier than the electric generator for any period of discharge. The hydraulic pump also is lighter than the hydraulic accumulator except for a demand of less than 2 sec. The electric and hydraulic methods, therefore, utilize energy storage only for extremely short duration operation and for surge protection.

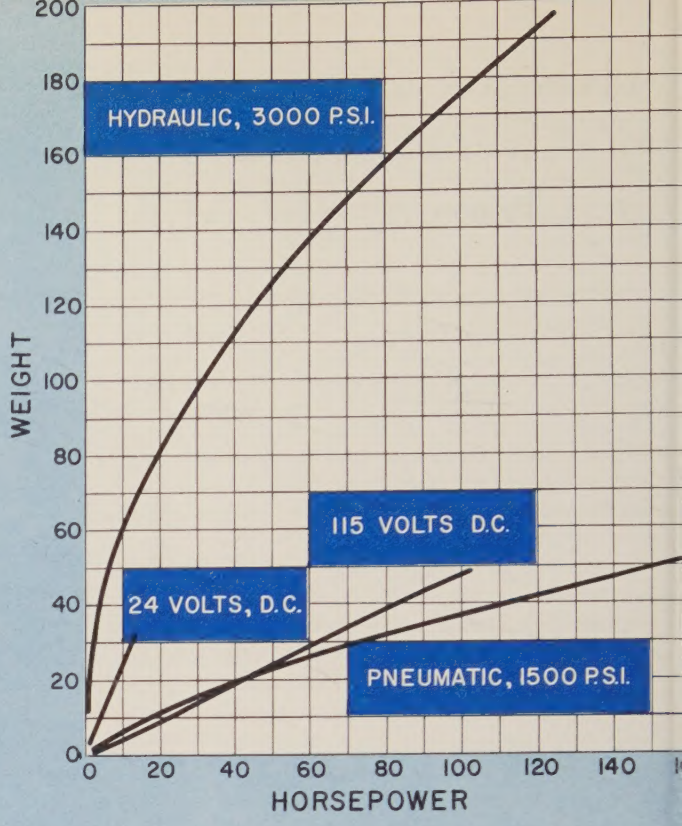


Fig. 3—Transmission-line weights of the three methods of actuator operation as required to transmit power 75 ft. The electric system uses a grounded return and a single power lead plus two control leads. The hydraulic system uses both a pressure and a sump line. The pneumatic system operates at a pressure of 1,500 psi and uses a single transmission line, exhausting into the atmosphere at the actuator.

both d-c and a-c generators. These data can be plotted logarithmically as almost a straight line. Note the trend of reduced specific weight as horsepower is increased. This may be somewhat misleading, as the gains made in the large generators are not due to size alone. The larger generators have been built in later years and reflect improvements in insulation as well as the effects of higher operating temperatures, blast cooling, and higher drive speeds. Perhaps the curve should show a distinct leveling off at higher horsepower values.

There is a definite reduction in weight of the a-c generator over the d-c version. This is especially true in the larger generator sizes where the specific weight appears to level off at 2.0 lb per hp. The short-term overload capacity of an electric generator for a period of as much as 5 min is approximately 125 per cent and this allowance should be made in selecting a generator for most actuator requirements. The weight and the constant-speed drive, of course, penalize the a-c generator. The requirements of a constant-speed drive vary between piston engines and gas turbines. The latter type permits a smaller variation between normal and maximum speeds. The overall efficiency of the generator shows an improvement within both the a-c and d-c types with an average value of 73 per cent for the smaller sizes and a mean of 83 per cent for the larger sizes.

Hydraulic Pumps

Fig. 1 also shows a plot of the specific weights of 1,500 lb per sq in. and 3,000 lb per sq in. hydraulic pumps of the engine-driven types. Again, there is much the same trend as the electric generators. Since there is a wide variation in the types of hydraulic pumps and in the associated valving required to maintain the desired flow, it is more difficult to establish the mean curve. As is to be expected, the higher pressure pumps show a lower specific weight because the delivered horsepower of a constant-displacement pump varies directly with pressure. In a constant-pressure system, the hydraulic pump has very little overload capacity as far as output horsepower is concerned. The specific weight of the 1,500 lb per sq in. pump has an asymptotic value of 1.0, while the asymptotic value for the 3,000 lb per sq in. pump is approximately 0.5.

The overall efficiency (volumetric plus mechanical) of a hydraulic pump at rated load does not differ greatly from that of an electric generator. Values of 75 per cent for small sizes to values as high as 90 per cent for larger sizes may be obtained. The part-load efficiency, like that of the electric generator, is lower than the full-load value.

Pneumatic Compressors

There are less available data concerning high-pressure pneumatic compressors for aircraft use than there are for generators and pumps. The high-compression ratio needed, especially for high-altitude operation, requires the use of several stages. For that reason, high-pressure compressors are not built in as large sizes as are either the hydraulic or electric generators. The specific weight of one

make of compressor varies from 186.5 lb per hp in the 0.016-hp size to 40.1 lb per hp in the 0.523-hp size. The pneumatic compressor also has a lower efficiency than either of the other two.

Power Storage

Aircraft actuators are used intermittently, and the integrated power demand of a series of actuators is so small that power storage appears, at first glance, to be attractive. Electric energy for aircraft is stored in much the same way that it is for automobiles. The lead storage battery for aircraft use, therefore, is only a fraction lighter than the automobile battery for a given energy storage, and storage batteries built by different manufacturers are based on standardized design procedures.

The ability of a storage battery to deliver its stored energy is dependent upon the rate at which it is to be delivered. Increasing the rate drastically reduces the amount of stored energy that can be removed from the battery at one time. For short time periods, however, the battery recovers and, except for the greater I^2R losses, delivers approximately the same total energy whether that energy is taken in short spurts at high current or as a continuous drain at a low current.

The specific weights of both hydraulic and pneumatic accumulators, or power-storage devices, are shown in Fig. 2. For both types there is a reduction in specific weight in the larger sizes. The specific weight of both types of accumulators includes the weight of the working-fluid pressure plus the weight of the compressed gas of the hydraulic accumulator. The method by which both air and oil are stored under pressure is well known and is not discussed here. The weight values used in plotting the chart in Fig. 2 were supplied by manufacturers of aircraft accumulators and the values show a definite similarity. The pneumatic accumulators have lower specific weight, as can be expected, since all their volume is usable.

In comparing the relative specific weights of either a generating or storage medium as power sources for a given actuator, the data in Fig. 2 are of interest to the aircraft-design engineer in a number of ways. The storage-battery line does not cross the generator line for any period of actuator discharge. For a load with a time duration of 20 sec, a storage battery weighs three times as much as a generator with equal capacity. For this reason, a storage battery is used to provide power only when the primary source of power is inoperative and to offer some voltage stabilization with fluctuating loads.

A hydraulic pump is also lighter than a hydraulic accumulator except for a demand of less than 2 sec. This indicates that the hydraulic accumulator is not used for the storage of energy but rather is used to absorb shock or surge in the system and to simplify the problem of unloading the hydraulic pump when the system demands are negligible.

When the pneumatic compressor with its high specific weight is compared with its air-storage-cylinder accumulator, the results are strikingly different. For any operation less than 4 min, it is lighter to store rather than to generate the energy. This is even more pertinent if the compressor is motor-driven, rather than engine-driven.

From Fig. 2, the following conclusions can, therefore, be drawn:

(a) Electric and hydraulic methods use energy storage only for extremely short-duration operation and for surge protection.

(b) The pneumatic method uses large storage capacity with the minimum possible size of compressor.

(c) Power for actuator operation when the prime source of power is shut down should be provided by a storage battery for long-term demands (over 20 sec) and by either a hydraulic or pneumatic accumulator for short-duration demands. For repetitive short-term demands, it is desirable to use an electrically driven pump to charge an accumulator rather than use either a large accumulator or a large storage battery with a high discharge rate.

Power Transmission

The electric actuator system in aircraft uses a grounded return for d-c transmission and a 3-wire grounded neutral for 3-phase a-c transmission. Conductor size is determined by current density as well as voltage drop, and rigid specifications define the allowable limits for each. In military aircraft, conduit is seldom used. The computation of wire weight for any amount of power to be transmitted is very simple and follows conventional techniques. Aluminum is used for the larger sizes of cables to save weight. The use of high voltage, either alternating current or direct current, is imperative in large aircraft for everything but the smaller size actuators.

Aluminum tubing is used for both hydraulic and pneumatic transmission in those areas not subject to temperatures above 300° F. For higher temperatures, stainless-steel tubing may be used.

Fig. 3 is a plot of the transmission-line weight necessary to transmit power 75 ft by the three media of actuator operation. The electric system uses a grounded return and a single power lead plus two control leads. It is based on a maximum voltage drop of 2 v on a 24-v system and on current ratings of the Army-Navy Specification AN-W-14a.

The hydraulic system makes use of both a pressure and a sump line. Tube size is chosen to permit a transmission efficiency of 90 per cent at —20° F. This is a rather severe basis for computation. An aircraft-design engineer may compromise somewhat on transmission efficiency to obtain a minimum overall system weight. The specific transmission weight of fluid at 3,000 lb per sq in. is lower than at 1,500 lb per sq in. for the same tubing stress and, thus, is used in this comparison.

The pneumatic system uses a single transmission line. This is made possible by exhausting directly into the atmosphere at the actuator. An operating pressure of 1,500 lb per sq in. was chosen and the transmission efficiency was computed at 90 per cent. Temperature has a negligible effect.

The weight of both the hydraulic and pneumatic transmission systems includes the weight of the working fluid.

Power Utilization

The means by which the power transmitted to the actuator is transferred into useful work by the actuator is dictated by the mechanical design of the structure to be moved. The output motion may be either linear or rotary, and the stroke-force relationship varies over wide limits. In the larger sizes, however, linear actuators fit into the structure more conveniently. In this paper, linear actuators only are considered.

In the design of an electrical actuator, the motor, gear reduction, and screw are often coaxial and the complete assembly is installed much the same as a

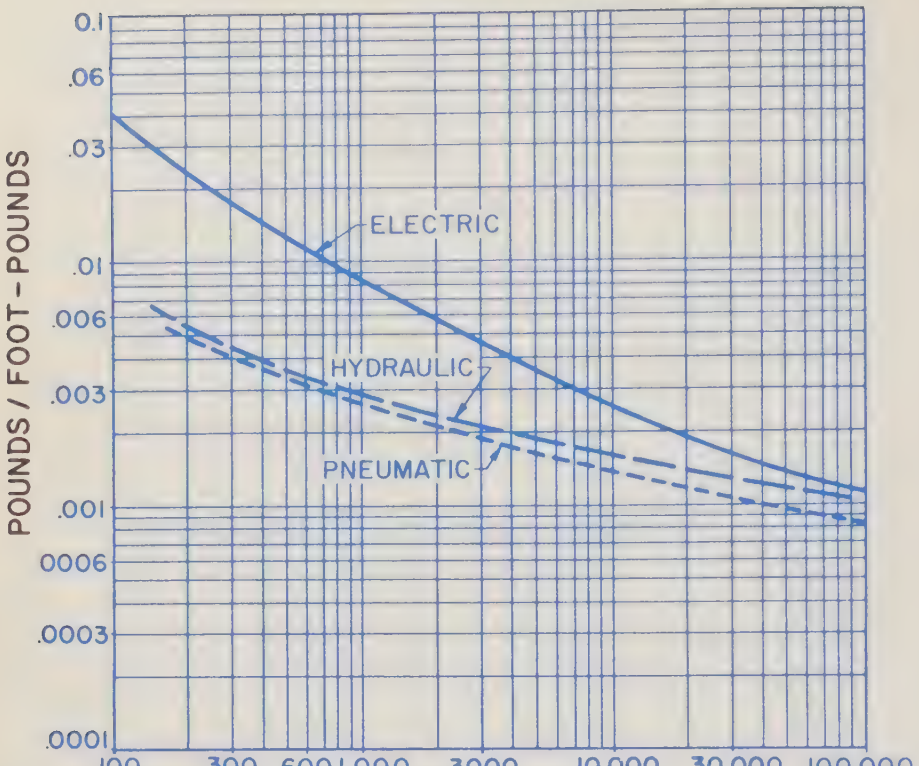


Fig. 4—Comparison of the specific weights of the three types of linear actuators at various capacities. The electrical actuators may vary from the trend shown if they have either a very short operating time, necessitating a large motor, or a long operating time, permitting a small motor with a higher gear ratio. The pneumatic actuators shown represent actuators that are hydraulic actuators used with compressed air. Actuators designed specifically for pneumatic operation may be somewhat heavier.

hydraulic cylinder. The motor is totally enclosed and is rated for short-time intermittent duty with the motor case forming part of the structure. Because of the high efficiency of the ball-bearing jack screw, even in the reverse direction, and the high efficiency of the gear-reduction assembly, the motor is provided with a magnetically released brake to prevent the unit from slipping under load. The motor diameter-to-length ratio is kept low to reduce starting time and to minimize the kinetic energy to be absorbed in the brake.

The size of the ball-bearing jack screw is dictated by the Brinelling capacity of the nut as well as by column strength of the screw. If the actuator is operating purely in tension, the screw can be smaller in diameter. The smaller sizes—usually under 1,500 ft-lb, where efficiency is an important factor—use a ball-bearing screw. For any one output rating, actuator weights may vary as much as three to one because of a variation in force-stroke combination and variation in operating time. There is, however, a distinct trend which the specific-weight curves drawn in Fig. 4 illustrate. The electrical actuators vary from this trend if they have either a very short operating time, necessitating a large motor, or a long operating time, permitting a small motor with a higher gear ratio.

The overall efficiency of the larger size electrical actuator varies from 40 per cent to 70 per cent. For smaller sizes, these values are lower because overall efficiency is not important when compared to the weight reduction that can be realized by other means such as by simplified gear boxes.

The specific-weight curve for hydraulic actuators in Fig. 4 represents a series of 20 hydraulic actuators of various sizes. These data show a smaller spread than in the case of the electrical actuators because the size of a hydraulic actuator is independent of its rate. The values given are for production units designe for a particular installation and for a operating pressure of 1,500 lb per sq i Fig. 4 shows the same relationship f pneumatic actuators. The pneumat actuators are simply hydraulic actuato used with compressed air rather than o and do not have provisions to limit trav rate. Actuators designed specifically f pneumatic operation may be somewha heavier than shown in Fig. 4.

Discussion of Hydraulic, Pneumatic, an Electrical Methods.

A comparison of the three types o actuators is illustrated by the bar charr of Fig. 5. To indicate the effect of dif ferent rates of operation, the selected loa of 3,000 ft-lb is shown at four rates— 2 sec, 6 sec, 18 sec, and 54 sec. The size and rates were picked hypothetically t cover the entire field of possible operatio

The code block at the top of the char shows that the bottom-most section o the bars represents the actuator weigh plus the weight of the operating mediun The specific weight of an electric actua tor for an 18-sec operating cycle is ob tained from Fig. 4. The horsepower o this actuator then may be computed assuming an overall efficiency of 50 p cent for the 3,000 ft-lb load.

The specific weights of the hydraul and pneumatic actuators also are take from Fig. 4 and then, assuming a actuator efficiency of 95 per cent, th horsepower for each of the operatin times may be computed.

The next division of the bars represent the weight of the generating source. Fo the electrical method, a generator size arbitrarily chosen four times the demand of the actuator, has been selected and the generator specific weight taken from Fig 2. This is multiplied by the sum of the motor power plus line losses to give a value of generator weight chargeable t this actuator. If, in the event a four times-actuator-power demand for the 2-sec actuator operation dictated a gen erator larger than is being built, the specific weight of the largest size being produced is used. The same specific generator weight has been used for each of the same size actuators when operat ing at a slower rate. It is assumed tha 10 per cent of the energy used by the actuator is provided by the battery therefore, an allowance is made for thi in plotting the generator weight.

To determine the weight of the gen

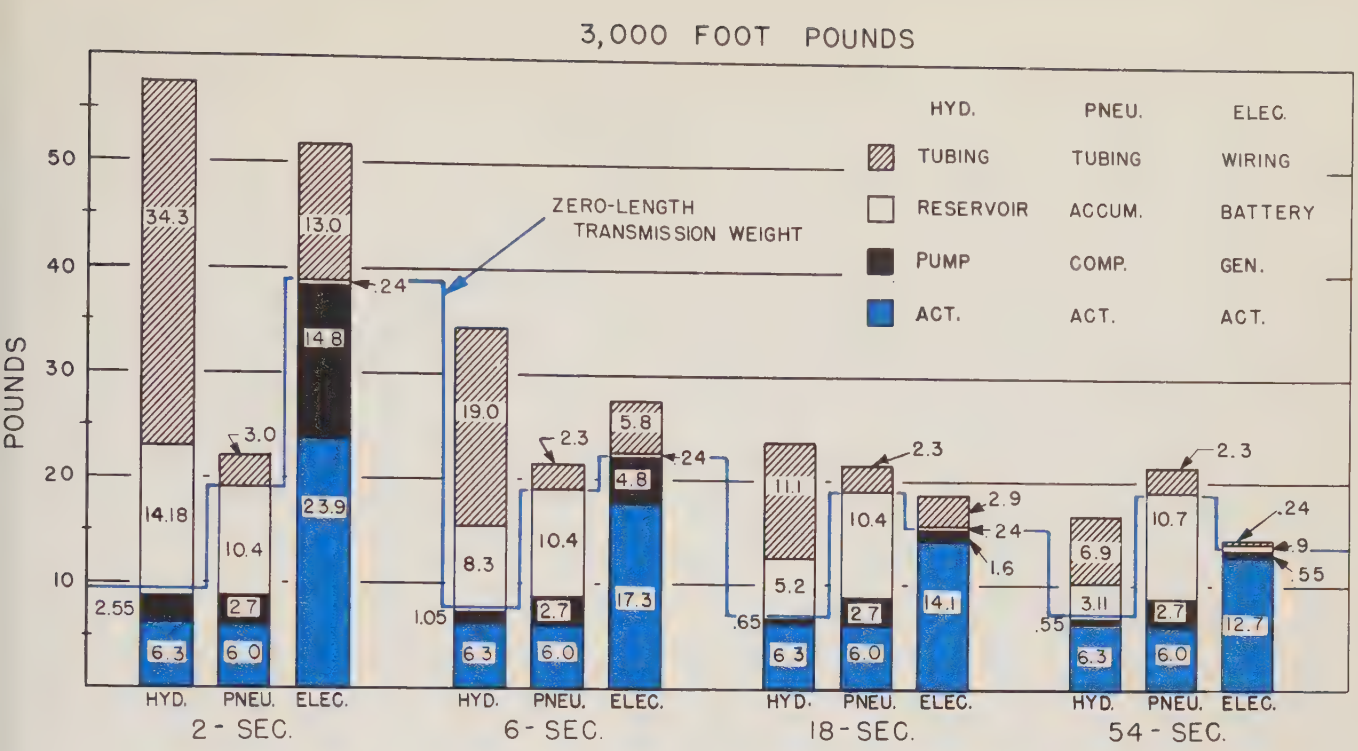


Fig. 5—Overall comparison of the three types of aircraft actuators, based on a selected load of 3,000 ft-lb, operating at various time durations. Since the greatest weight in the hydraulic method and the lowest in the pneumatic and electric methods is in the transmission of power, a line can be drawn through each of the bars in the chart cutting off the transmission weight and its proportional share of storage weight. This line (shown above in color) indicates the weight of each method at a minimum transmission length.

erator source using the hydraulic method the weight of a pump to supply the actuator power, plus line losses, may be computed by using the specific weight of a pump with a power output four times the demand of the 2-sec actuator rate. To this may be added the weight of an accumulator capable of supplying 10 per cent of the energy. This same section of the pneumatic bar represents only the compressor and is not a direct comparison with the other two methods since the main source is carried in the storage section. The compressor must be the minimum size to recharge the storage in a 20-min period.

The storage weight is represented by the third-from-bottom section of the bar. This section in the pneumatic bar represents the weight of the air bottles plus the air weight and was computed on the basis of two complete cycles of actuator operation (per Army-Navy Specification AN-P-86). In the hydraulic bars it represents the weight of the reservoir plus 120 per cent of the oil in the entire system. Storage in the electric method represents only the weight of 10 per cent of capacity in storage battery weight.

The top section of the bars represents the transmission weight for a 75-ft distance. The transmission weights for all of the systems were obtained from the chart shown in Fig. 3.

An examination of Fig. 5 shows that the pneumatic method is the lightest in the first two cases (2-sec and 6-sec time cycles) and the electric is the lightest in the longer time cycles. The pneumatic method is practically constant for all operating rates, whereas both the hydraulic and electric start out heavy and nearly equal and then taper down to be very close to the pneumatic weight at the 54-sec cycle. Hence, in the shortest time cycles the pneumatic method shows a very definite weight advantage, but in the longer time cycles any of the three methods could be used with the slight margin of advantage going to the electric method. It should be pointed out that the actuator weights for both the hydraulic and pneumatic methods are the same and constant for all operating rates. In fact, the pneumatic method is composed of constants, and the bar chart shows it is constant for all rates.

The larger variables in the hydraulic method are present in the tubing and storage. For the electric method, the larger variables exist in the actuator and the generator.

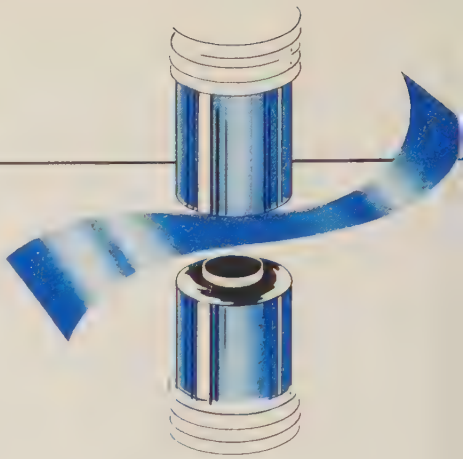
Since the greatest weight in the hydraulic method and the lowest weight in the pneumatic and electric methods are in the transmission of power, a line can be drawn through each of the bars in the chart, cutting off the transmission weight and its proportional share of storage weight. This line, then, indicates the weight of each method at a minimum transmission length. The hydraulic method is then shown to be the lightest for all rates.

Summary

The trend can be summarized as follows: as the load is increased, the electric actuators can be used to more advantage. Also, with longer transmission distances and with decreasing operating rates, the electric actuators should be used.

With greater loads and at greater distances with faster operating rates, the pneumatic actuators are the preferred choice. With low and normal loads at minimum transmission length, the hydraulic actuators should be used for all rates. However, as the loads are increased, the electric method gains an advantage over the hydraulic at the lower operating rates.

A Case Study: Applying Industrial Electronics to Thickness Measurement of Non-Ferrous Strip



The ability to measure accurately the thickness of copper strip insures that the material will have the necessary requirements for the final product and makes possible economies in the cost of the material. To make such measurements without any effect on the material itself and to do this at speeds consistent with production requirements was a problem presented to the General Motors Process Development Section. Applying fundamental concepts of physics, engineers developed an electronic strip gage which not only fulfilled these requirements but provided other advantages not anticipated.

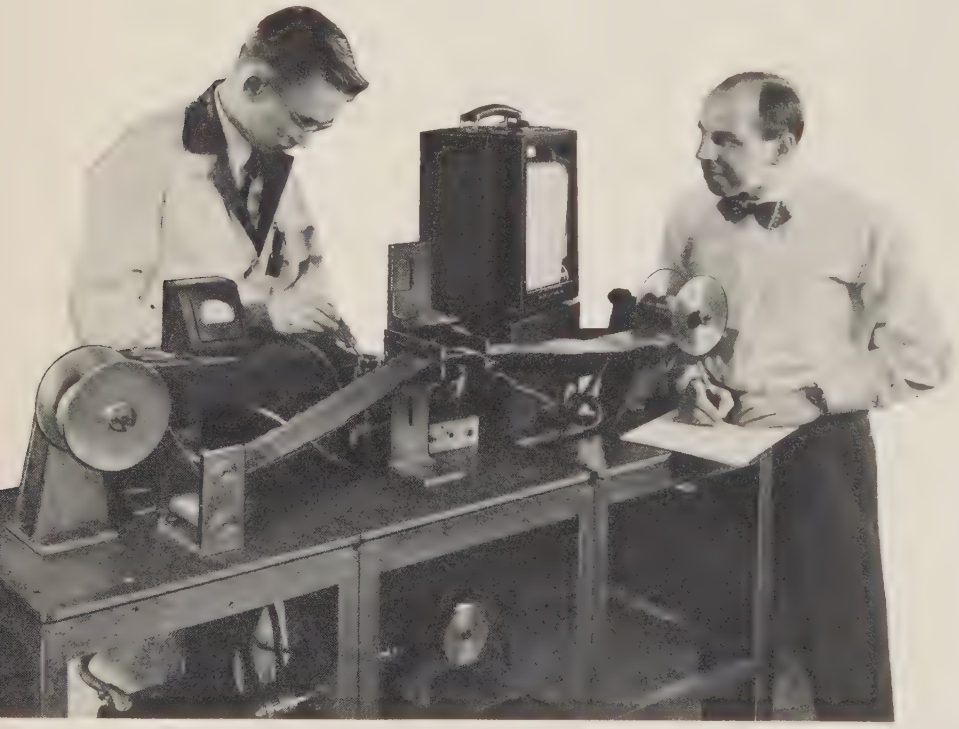


Fig. 1—The workability of a gage using the principle of shielding effect was demonstrated early in its development by this laboratory model. The proper frequency range for the material to be measured in the gage was determined from tests with this device.

A PROBLEM encountered in one of the GM Divisions some years ago was to measure the thickness of copper strip. The copper in question was 0.003 in. to 0.006 in. thick and was used in the manufacture of automobile radiators. The importance of close measurement was evident from the fact that, if the copper was too thin, an unsatisfactory product would result. Furthermore, considerable economy in copper costs could be effected if good gaging would permit operating closer to the lower limit of the usable-size range.

The use of conventional measuring devices for this application was limited because the copper was so soft that even the most delicate contact would mark it. Any little dimple or speck of dirt would introduce an error in measurement in the order of magnitude of the accuracy desired. Some non-contacting method, therefore, had to be devised.

The developmental work for a suitable gage was undertaken by the GM Process Development Section.

Absorption of X-rays, beta rays, or gamma rays was considered but rejected because of the potential hazards to personnel from the radiation source if tampered with. (Gages based on these principles are now in use.)

It seemed as though the well-known shielding effect of copper could be used as the basis of a measuring system. The absorption of electromagnetic waves by non-ferrous metals is related to the frequency of the energy, the conductivity of the material, and its thickness. If the conductivity is reasonably constant, the frequency can be controlled and the only remaining variable would be the thickness.

A simple experimental approach to the problem was taken as a first step. A preliminary setup was made using an oscilloscope, an audio-signal generator, and two relay coils between which a strip of copper was passed on plastic supports. The device quickly demonstrated that a practical gage might be developed based on the shielding-effect principle. The larger task remained of working out the details of a sensitive, reliable gage.

Experiments were performed to establish the proper frequency at which to operate for the thickness range and conductivity of the material being measured. Circuitry was developed and a mockup of the whole gaging setup was made (Fig. 1). With this mockup, a large quantity of material could be measured under fairly typical operating conditions for the proposed gage. Final details were worked out and a complete unit was designed and built. Fig. 2 shows the completed strip gage as it was finished

By ROBERT B. COLTEN
Process
Development
Section

Putting the "skin effect" to work in the factory

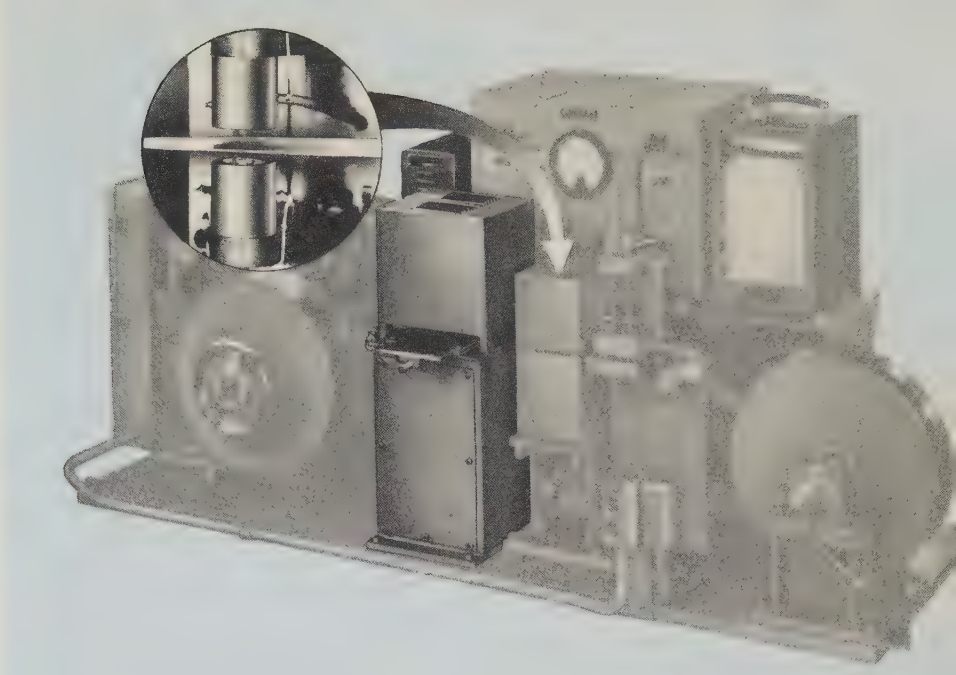


Fig. 2—After developmental work, this model of the copper-strip gage was built by the GM Process Development Section for delivery to the manufacturing plant. Copper strip feeds from right to left on rolls and passes through the thickness-measuring portion (gaging coils shown inset) followed by the pinhole detector. The pinhole detector, a photoelectric device with amplifier and relay circuit, is shown outlined in the above illustration.

for use in the plant. Three such gages are now in use in GM plants, checking about 10 per cent of the automotive-radiator stock for quality purposes.

To understand the operation of this gage, it is appropriate to review a few concepts well known to physicists and electrical engineers. When a conductor is located in a varying magnetic field, a difference in potential is induced as expressed by the familiar equation:

$$E = -\frac{d\phi}{dt} = -\int \frac{d}{dt}(B\cos\theta)\,ds. \quad (1)$$

If the conductor is part of a closed circuit, a current flows which produces a magnetic field of its own opposing the original field, according to the well-known Lenz's Law. In the case of the copper strip under study, the current flowing in the metal is known as *eddy currents*. The actual power loss, P_e in watts per cm³, due to these eddy currents can be determined from the following expression:

$$P_e = \frac{1.64\ (tfB_m)^2}{\rho\ (10^{16})} \quad (2)$$

where

P_e = Power loss due to eddy currents (watts per cm³)
t = thickness (centimeters)
f = frequency (cycles per second)
B_m = maximum flux density (gauses)
ρ = resistivity (ohms per cubic centimeter).

The induced current tends to crowd to the surface, decreasing exponentially with depth. This is called the *skin effect* and the depth at which the magnitude of the current has decreased to $1/e$ (37

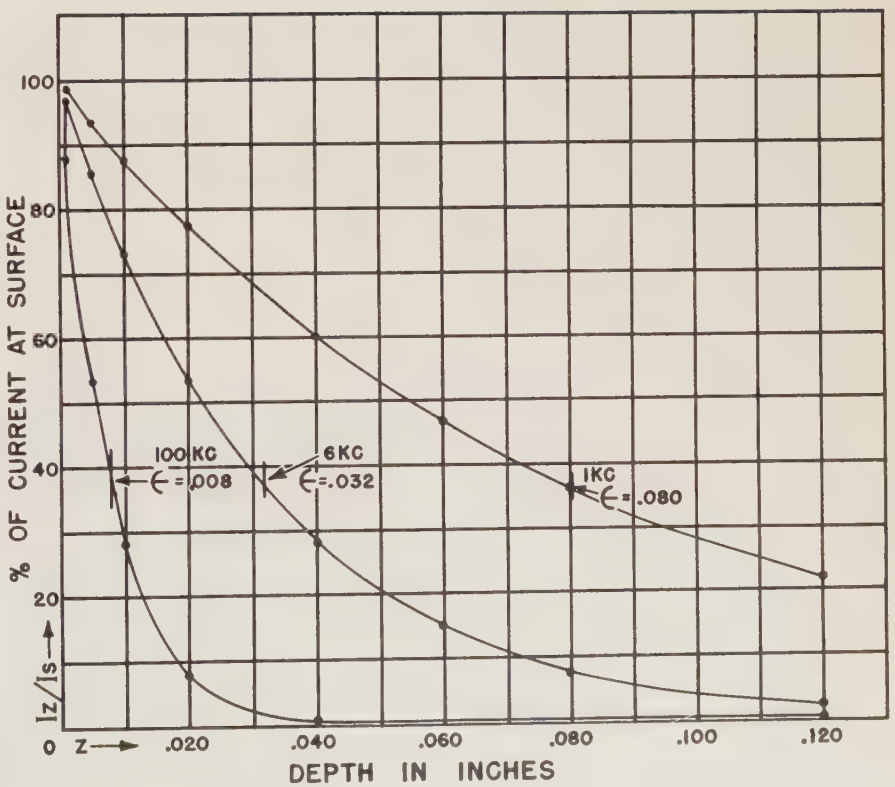


Fig. 3—Using equations (3) and (4), these curves can be plotted showing the calculated decrease of current with depth for three different frequencies and skin depths, as marked.

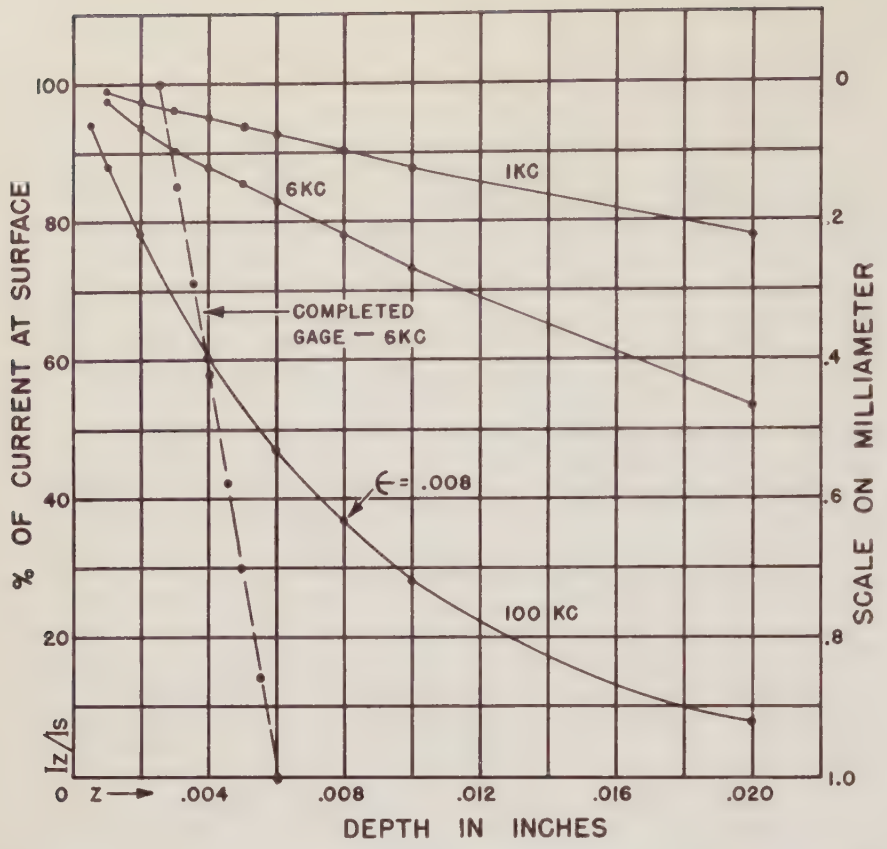


Fig. 4—This chart shows calculated curves for three frequencies and the calibration curve for an actual gage. Almost perfect linearity is attained for a short range although the function is non-linear.

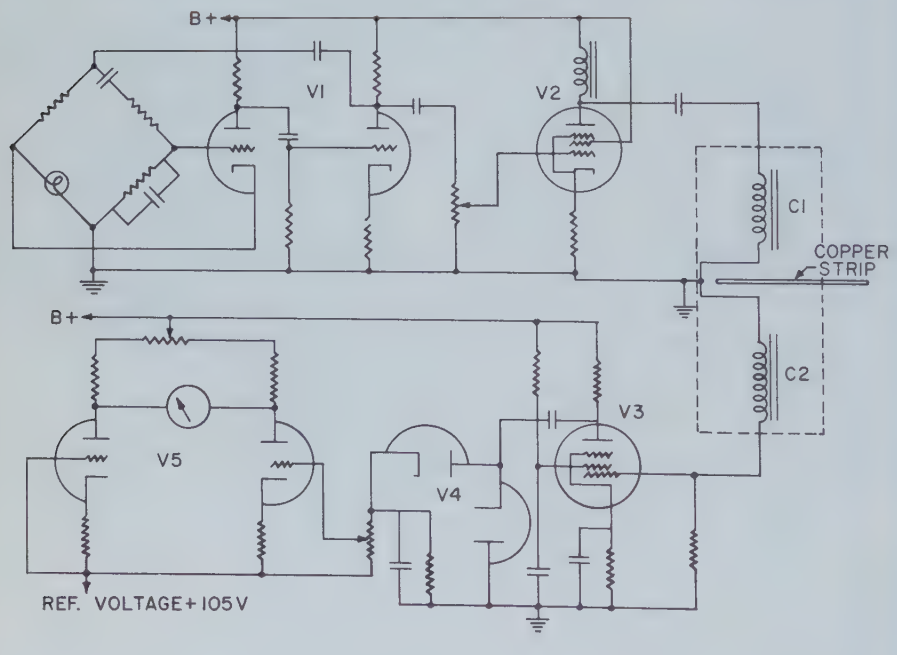


Fig. 5—The principal components of the electronic strip gage are indicated in this circuit diagram. **V1** is a Wein Bridge oscillator, **V2** is the power amplifier, **C1** and **C2** are transmitting and receiving coils, respectively, **V3** is an amplifier, and **V4** is a voltage-doubler rectifier. The rectified signal is applied to one grid of a balanced plate meter circuit, **V5**.

per cent) of its value at the surface is known as the *skin depth*. The following equation for skin depth ε in centimeters can then be written as:

$$\varepsilon = \frac{1}{2\pi}\sqrt{\frac{\rho(10^9)}{\mu f}} = 5{,}033\sqrt{\frac{\rho}{\mu f}} \qquad (3)$$

where

ε = skin depth (centimeters)
ρ = resistivity (ohms per cubic centimeter)
f = frequency (cycles per second)
μ = permeability.

The current at a depth Z, in centimeters, is related to the current at the surface as follows:

$$\frac{I_Z}{I_S} = e^{\frac{-Z}{\varepsilon}} \qquad (4)$$

where

I_Z = current at depth Z
I_S = current at the surface.

Equation (4) is usually recognized as being valid only when the effective thickness of the conductor is more than three or four times the skin depth. However, in this study, which was concerned with thicknesses of about one-eighth of skin depth, it was found that when curves were plotted using equations (3) and (4), these curves fit the experimental data very closely (Figs. 3 and 4). It was also noted that although the function is non-linear, almost perfect linearity is attained for a short range.

For a successful gage, it was necessary to select a frequency that provides the maximum sensitivity and best linearity for the size range of the material to be used. A frequency was selected, therefore, that gives a skin depth much greater than the thickness of the material. A frequency of 6,000 cps was used for the copper-strip gage to measure from 0.003 in. to 0.006 in.

Most of the electronic techniques employed are apparent when a study is made of the circuit diagram used in building the first gage (Fig. 5). The transmitting coil **C1** is excited by a power amplifier **V2** driven by a Wein Bridge oscillator **V1**. The receiving coil **C2** feeds its signal into an amplifier **V3** and voltage-doubler rectifier **V4**. The rectified signal is applied to one grid of a balanced plate-meter circuit **V5**. (Note that the cathodes of the meter tube are connected to a reference voltage. This permits examination of a small change

in signal after considerable amplification.)

As it frequently happens when a better way of measuring is found, the use of this copper-strip gage revealed unexpected but pertinent information. As roll after roll of copper was run through the gage, it became apparent that a similarity existed in the chart recording from roll to roll. It was noted that when the recordings from any two rolls were compared by placing one over the other, a perfect match was obtained. The resulting pattern of the recording was the "signature" of the particular rolling mill which rolled the copper and, as long as the coolant, roll pressure, and shape of the rolls was not altered, the signature or similarity would exist. This suggested a method of indicating when the bearings or rolls on the mill needed alteration.

The successful solution to the problem of designing a suitable copper-strip gage resulted in additional developments which could be applied to gaging. A pinhole detector was developed and built to be placed on the copper-strip gages (Fig. 2). This unit detects holes as small as 0.001 in. in diameter in a strip moving at better than 300 fpm. The pinhole detector is a photoelectric device of high sensitivity using a photomultiplier tube as the pickup and a very fast amplifier and relay circuit.

Another application of the shielding principle used in developing the copper-strip gage was made in measuring the thickness of the walls of an aluminum casting (Fig. 6). The resulting gage was built with a non-linear scale. This application utilized a very long section of the gage's performance curve, actually measuring a thickness ratio of 5 to 1. The gage operated at about 18 cps and the coils were not a fixed distance apart.

Summary

Thus, with the application of some fundamental concepts, engineers solved an industrial measuring problem enabling the manufacturing plant to improve product quality and reduce processing costs. In the quest for a solution to the initial problem, several additional applications of the principle were discovered.

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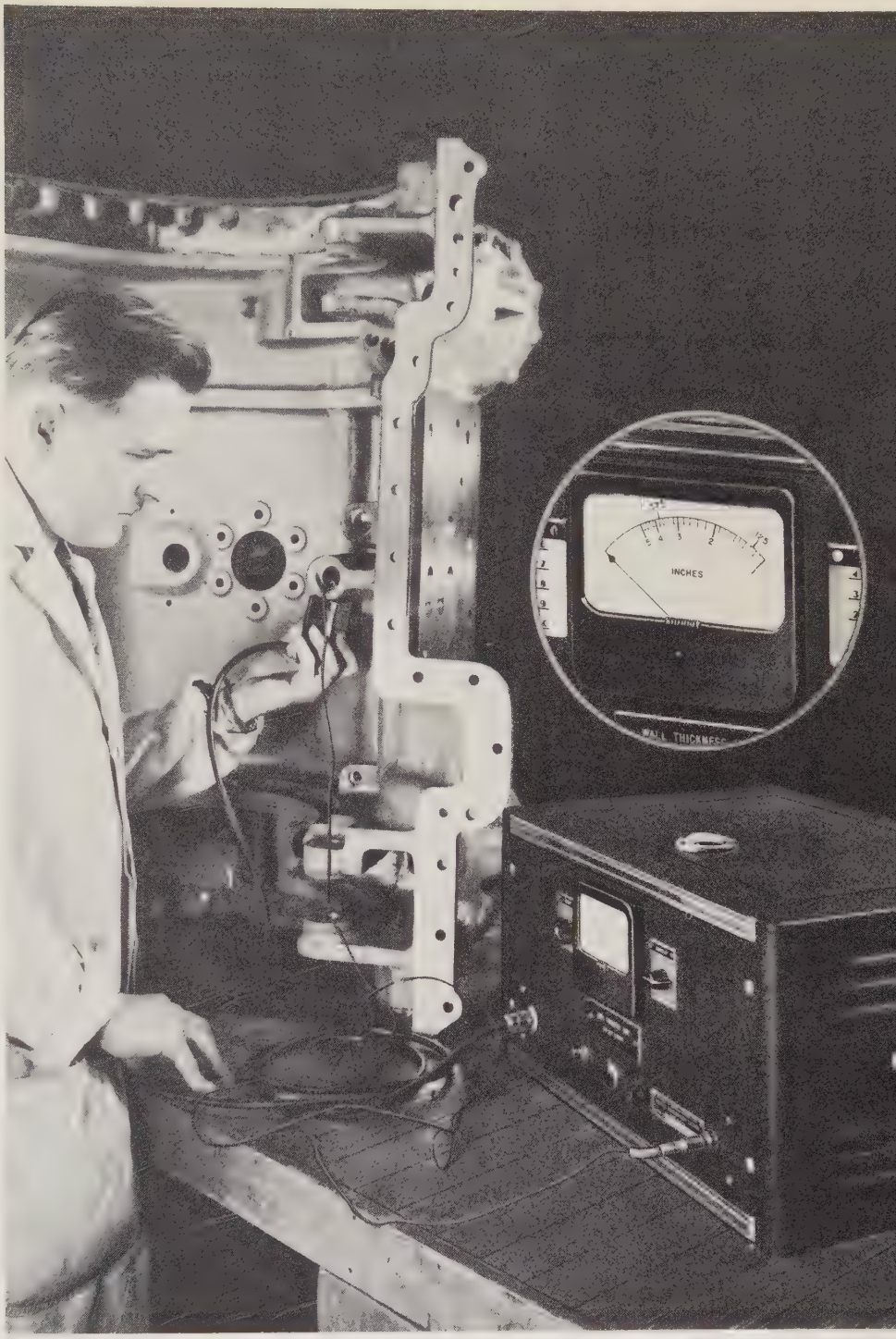

Fig. 6—Wall thickness of an aluminum casting is being measured by another gage developed as a result of the study using the shielding principle to measure the thickness of copper strip. This gage operates at a frequency of 18 cps and measurements are read on a non-linear scale (inset).

A New Machine for Endurance Tests with Stress Cycles of Variable Amplitudes

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The test track moves into the laboratory

An important phase of automotive design is that of designing component parts for long life. Knowledge as to the lifetime of an automotive vehicle's component parts results in economy for the manufacturer as well as for the buyer. The varying loads to which a vehicle is subjected makes it difficult to determine exactly the lifetime afforded by a particular component part or assembly. To overcome this situation a new machine has been developed by the Research Laboratory of Adam Opel A.G., Russelsheim, Germany. The machine subjects an automotive vehicle's component parts to the same loads as those encountered during actual driving conditions, gives an exact answer as to the number of driven kilometers a part will last before failure, and considerably reduces the time usually required to perform endurance tests.

BEFORE an automotive vehicle is placed on the market for purchase by the buying public it is thoroughly tested and analyzed in order to insure satisfactory performance under all types of operating conditions. Such factors as acceleration, rideability, fuel consumption, braking, and wear are investigated while the vehicle actually performs on a selected test track. To the engineer, the results of the investigations give an insight into whether the various component parts of the vehicle are functioning in actual practice as they were designed to do. To the prospective buyer of the vehicle, the investigations and testing work establish information on performance, comfort, economy of operation, safety, long life, and other desirable qualities wanted in an automotive vehicle.

The test track is the only logical place where a vehicle can be tested for such performance factors as fuel consumption, acceleration, and braking—efficiently, accurately, and in as short a time as possible. Investigation into the wear factor, on the other hand, with its resulting information on the lifetime of an automotive vehicle's component parts, is not readily adaptable to test-track procedure. The process of investigation is time-consuming and the information obtained is often of an estimative nature. The procedure usually involves driving a test vehicle for a certain number of miles on a selected test track which has available all types of road-surface conditions. At the end of the test, the car is dismantled completely and all component parts examined for wear. From the amount of wear indicated, the lifetime or length of service of each part is then estimated.

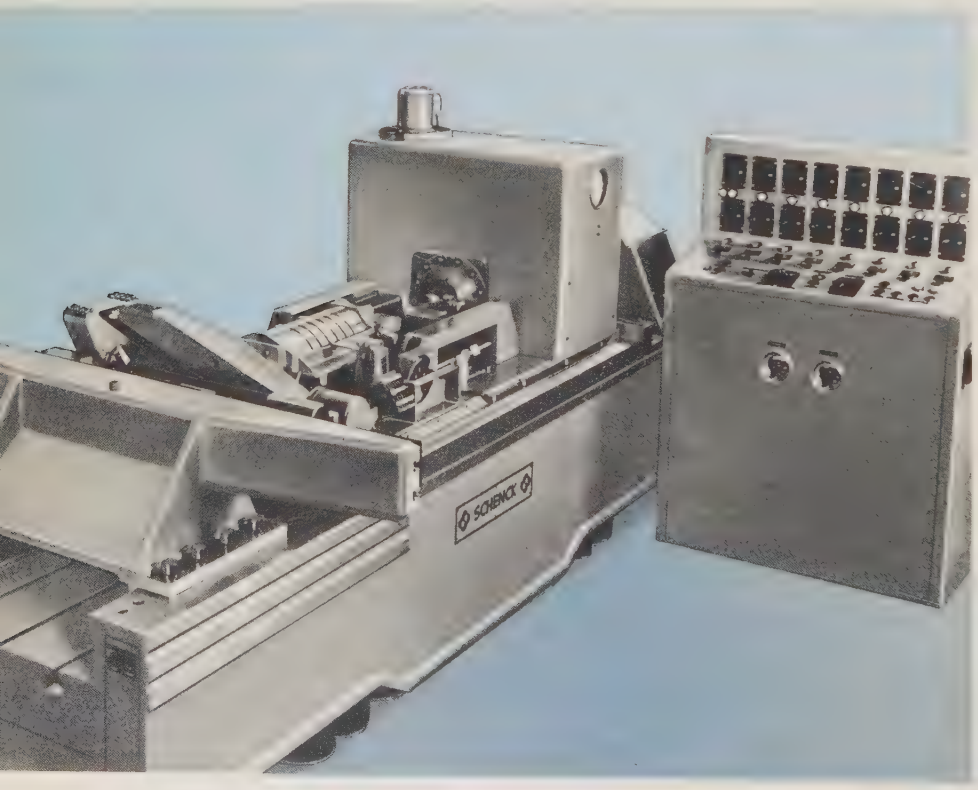


Fig. 1—Newly designed machine used for endurance tests on various component parts of an automotive vehicle. The machine is capable of performing endurance tests with stress cycles of variable amplitudes and duplicates a combination of stresses as produced by actual driving conditions on the road.

Using this method, it is not possible to obtain information as to the exact mileage a component part of the vehicle will render before failure occurs. Whereas such instruments as the fuel flowmeter, fifth wheel, and electric speedometer are used to obtain exact values for the vehicle's fuel consumption and acceleration, instruments of a corresponding nature are unavailable which will indicate readily the lifetime of a particular part. It is true that tests of the most elaborate character might indicate that a certain component part of a vehicle would theoretically stand a given amount of stress, but the theoretical values obtained from such tests might not compare with results obtained when the vehicle is subjected to actual driving conditions on road surfaces of all types.

In view of the time element involved in determining the wear factor and the resultant estimated-lifetime information of a vehicle's component parts, Adam Opel decided to investigate the possibilities of developing a machine which

would, in a sense, duplicate the stresses which such parts would encounter during actual driving conditions. The development of such a machine would represent the possibility of substantial cost savings through engineering. The longest lifetime of an automotive vehicle having the least weight is obtained when all of its component parts have the same lifetime. Exact knowledge pertaining to the lifetime of each component part would result in economy for the manufacturer as well as for the buyer of automotive vehicles.

Development Program

The loads to which the component parts of an automotive vehicle are subjected vary continually, depending on the driving conditions. The rear-axle shaft, for example, is under one loading condition when the vehicle is being driven on a smooth, concrete-paved highway and is under an entirely different set of loading conditions when it is being driven over rough, chuck-hole-riddled pavement. In addition to the changing load conditions encountered in the vehicle, the frequencies of the loads also are continually changing.

If a machine were to be developed which would accurately ascertain the lifetime of a vehicle's component parts, it would have to be designed in such a way as to duplicate the load conditions and their frequencies produced on the road under actual operating conditions or, in other words, perform endurance tests with variable load amplitudes.

Endurance tests performed with constant load amplitudes would not prove worth-while, as such tests only determine the lifetime of component parts always subjected to the same load, as on stationary engines operating at a constant number of revolutions per minute. In addition to performing endurance tests with variable load amplitudes, the new machine would have to perform such tests in a fraction of the time normally encountered when the usual methods of investigating lifetime were undertaken.

The developmental work was undertaken at the Adam Opel Research Laboratory. It was here that engineering research was applied to the fundamental engineering problems encountered in developing the new endurance-testing machine. When the last of the problems had been solved, design requirements and specifications were drawn up. The

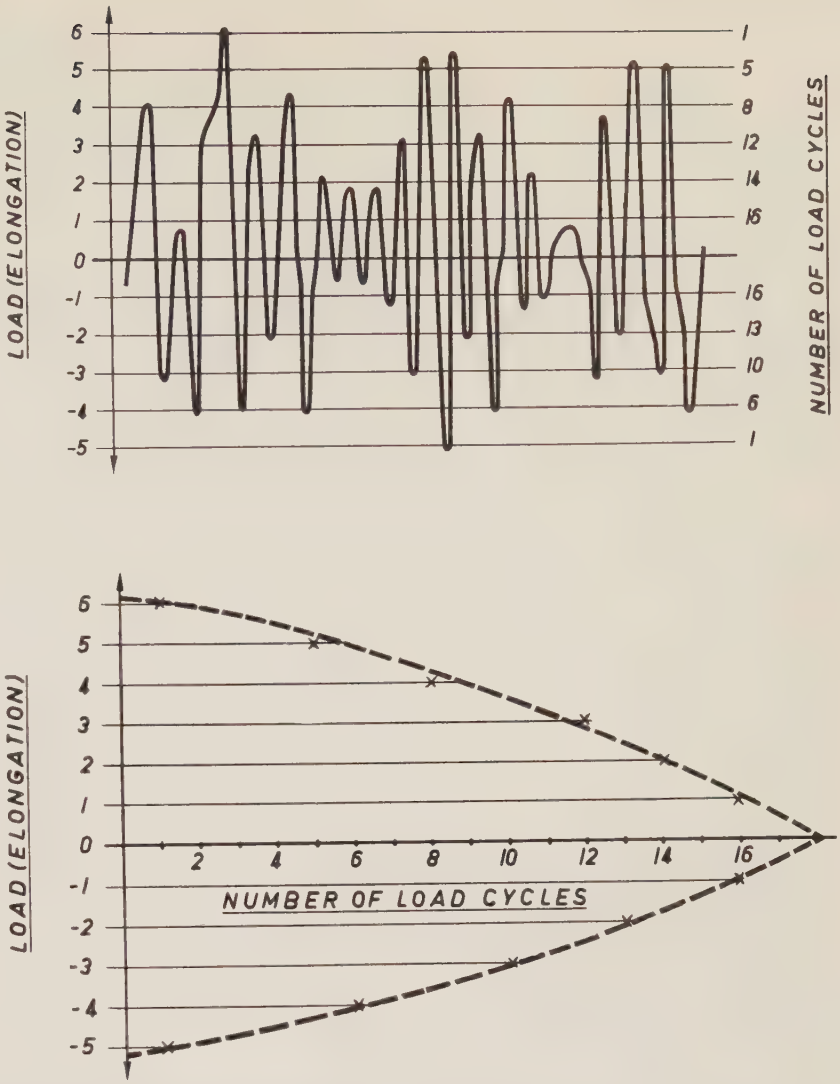


Fig. 2—Prior to performing an endurance test on the machine it is necessary to know all of the loads and their frequencies that a vehicle might encounter when driven over all types of road surfaces. Two types of instruments are used to record these various loads—pasted-on strain gages and mechanical-contact strain gages. (Above) Section of a measurement taken with pasted-on strain gages when used on a rear-axle shaft. This particular reproduced oscillogram is a measurement made during an 8-sec run over a very rough road and shows that a load of height 6 in. is obtained one time and a load of height 5 in. is obtained five times. Pasted-on strain gages are used for measurements recording the load or elongation curve.

actual construction of the machine was performed by the firm Carl Schenck of Darmstadt, Germany, making use of the experience and cooperation of Dr. Ernst Gassner of the Laboratorium fuer Betriebsfestigkeit, and under the instruction and supervision of the Adam Opel Laboratory. Fig. 1 shows a view of the completed endurance-testing machine.

Operation

The new endurance-testing machine is capable of subjecting a vehicle's particular component part or assembly to the same loads (elongations) and frequencies that the vehicle encounters under all types of operating conditions. Before the machine can be put into operation, however, all of the possible loads and their frequencies must be known. This information can be accurately obtained only by actual measurement on a vehicle as it is being driven over selected test tracks. The operation of the endurance-testing machine is dependent upon these measurements.

There are certain conditions which the selected test tracks must meet. The road conditions and the kind of driving depending on it must be such that the vehicle is subjected to all the normal loads usually encountered. The usual test track on which the load spectrum of the component part is measured is of such a length that the use of statistical methods is justified. To date, tests have

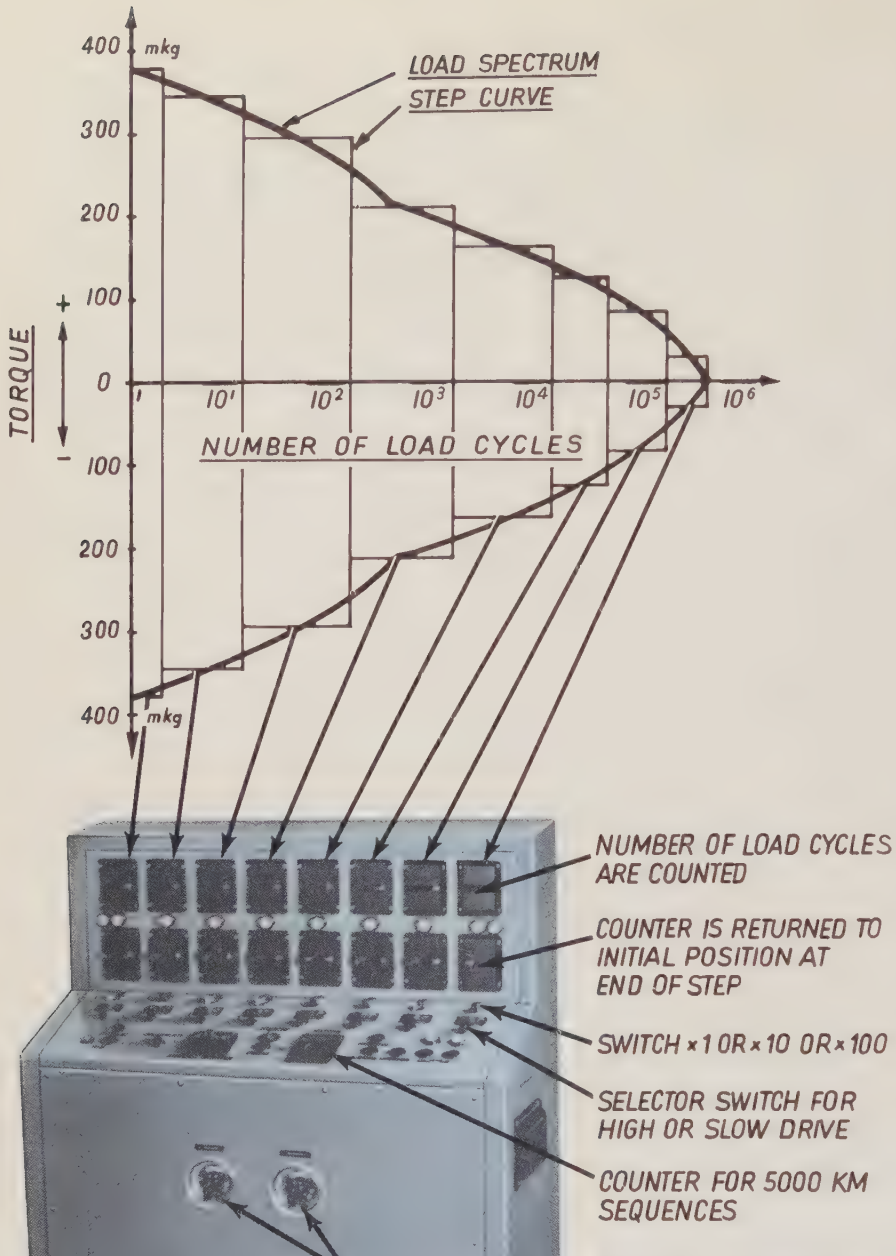


Fig. 3—Load spectrum for a rear-axle shaft as obtained from the endurance-testing machine. The number of load cycles corresponds to a distance of 5,000 km. Because the load amplitude cannot change continuously, the load spectrum is transformed to a stepped curve. A certain number of load cycles is coordinated in each step. The steps change automatically and are controlled from the switchboard of the machine (bottom). The component part under test is subjected to a complete load sequence which is equal to a driven distance of 5,000 km. The machine repeats the 5,000-km sequences until the part under test fails. The number of sequences which the part undergoes is counted automatically on the switchboard and the number of sequences shown, multiplied by 5,000 km, corresponds to the lifetime of the component part in driven kilometers.

proved that tracks of 200 km (124 miles) to 300 km (186 miles) are of sufficient length for most cases. In some cases, however, it is necessary to use special test tracks which are shorter in length. This is the case when it becomes necessary to measure special driving conditions in order to complete the load spectrum.

To measure the loads and their frequencies on a particular component part while the vehicle is in operation, two types of instruments are used—recording instruments (pasted-on strain gages) and counting instruments (mechanical-contact strain gages).

Pasted-On Strain Gages

Pasted-on strain gages are used at the present time for measurements recording the load or elongation curve. The gages operate an oscillograph through an amplifier. The evaluation of the resulting oscillograms for the load spectrum is a difficult and tiresome process but this method of measurement has been found to be very suitable for special driving conditions. The results obtained when information is desired on loads encountered during unusual driving conditions are highly satisfactory. Fig. 2 shows a section of a measurement taken with pasted-on strain gages when used on a rear-axle shaft. The section of the reproduced oscillogram shown is a measurement made during an 8-sec run over a very rough road.

Mechanical-Contact Strain Gages

Mechanical-contact strain gages are devices which open or shut one of several contacts, often in a certain ratio by means of a lever. The contacts are exactly adjustable to an elongation amplitude and give an impulse to a counter during the test run any time the adjusted amplitude is exceeded. For each point on the curve of the load spectrum, a run over the entire test track is required if a single-contact strain gage is used. These strain gages are usually made for each individual case and are screwed or soldered onto the component part in question. Each measurement directly gives a point on the load spectrum.

When complete information is available as to the loads and their frequencies encountered by a particular component part under all types of operating conditions, endurance testing by the machine can begin. The design of the machine allows endurance tests to be made for pulling, pressure, torsion, or bending. Special fixtures are required for each case when placing the component part to be tested in the machine. Fig. 3 shows a load spectrum for a rear-axle shaft as obtained from the endurance-testing machine. The number of load cycles corresponds to a distance of 5,000 km (3,107 miles). Also shown in Fig. 3 is the machine's switchboard control panel.

The design of the endurance-testing machine is such that the load amplitudes

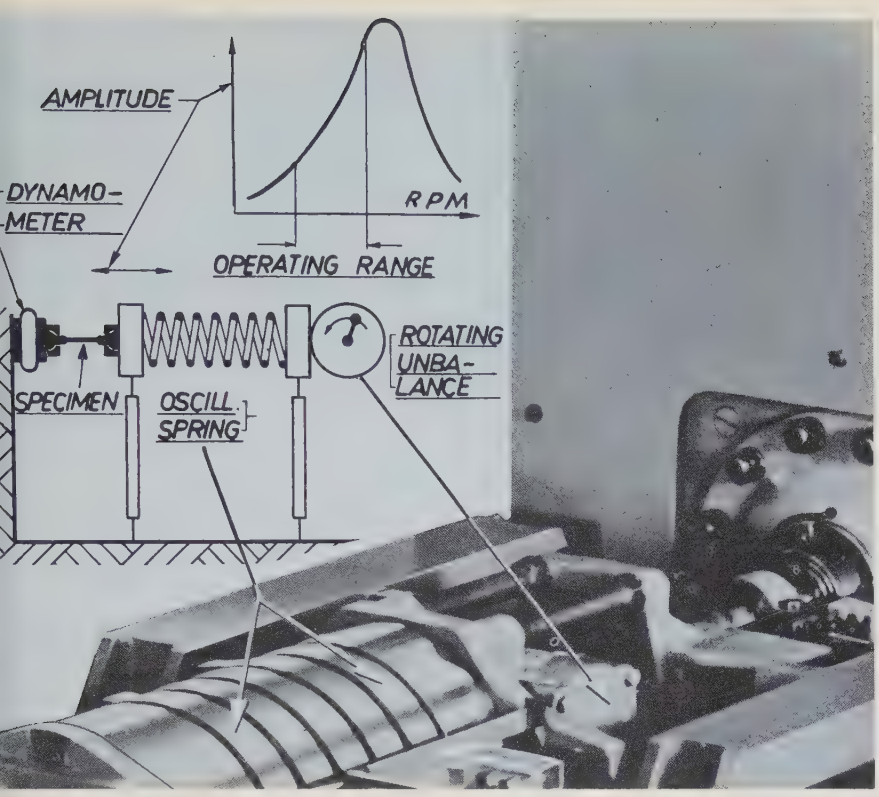
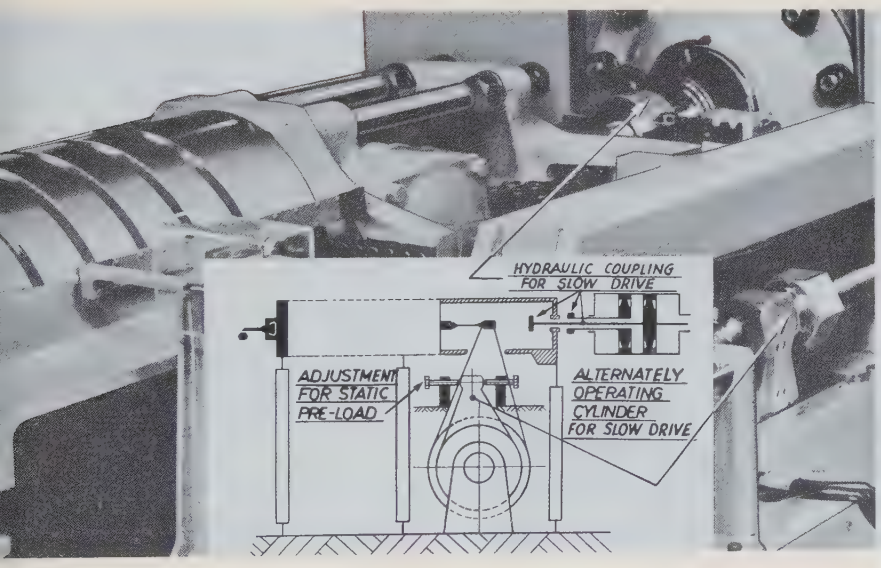


Fig. 4—Endurance-testing machine's resonance drive which is used to generate the smaller and medium loads having a high number of load cycles. This drive excites the oscillating spring-mass system by means of the rotating unbalance. The test frequency when the machine is driven by the resonance drive is 800 cpm to 2,000 cpm, depending on the rigidity of the component part under test. The maximum test stroke for the resonance drive is ±32 mm. The load amplitude is read optically on the dynamometer.



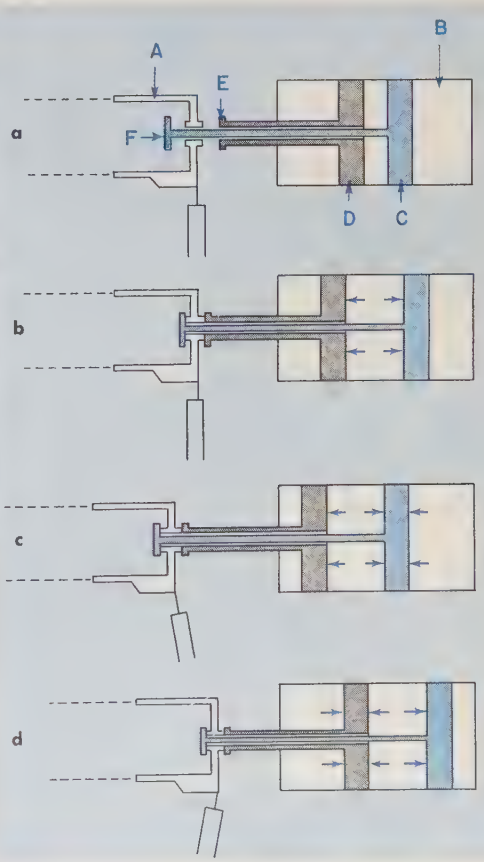


Fig. 5—(Above) Endurance-testing machine's hydraulic slow drive used to generate loads having a small number of load cycles. The test frequency is approximately 4 cpm and the maximum test stroke is ±50 mm. The static preload is adjusted only once, at the start of a test. (Right) Operation features of the testing machine's hydraulic-cylinder apparatus which serves two purposes: to act as a gripping device and as a low-frequency drive. The swinging member **A** is excited either by a resonance drive at high frequency or actuated by the hydraulic cylinder **B** at low frequencies. The hydraulic cylinder contains two pistons: **C** of solid-rod construction and **D** of hollow-rod construction. Both piston rods are flanged at the ends **E** and **F**. View *a* shows the pistons during high-frequency operation. When the testing machine is changed from high- to low-frequency operation, the resonance drive is switched off and fluid is pressed between the two pistons. When the two pistons are spread apart, the bottom plate of member **A** is gripped by flanges **E** and **F** in view *b*. Hydraulic pressure is then alternately applied to the end chambers of both pistons. This action imparts a reciprocating motion to both pistons as one unit and then to the swinging member **A** in views *c* and *d*.

cannot change continuously. The load spectrum, therefore, is transformed to a stepped curve as shown in Fig. 3. A certain number of load cycles is coordinated to each step and an equilization of steps is similar to normal integrating practice. The steps change automatically and are controlled from the switchboard of the machine. The component part under test is subjected to a complete load sequence of 5,000 km. The machine repeats the 5,000-km sequences until the loaded element breaks. The number of sequences which the part undergoes is counted automatically on the switchboard and the number of sequences up to the failure of the part, multiplied by 5,000 km, corresponds to the lifetime of the component part in driven kilometers.

Testing-Machine Operating Mechanisms

The endurance-testing machine incorporates two driving units for the generating of load amplitudes—a resonance drive and a hydraulic drive. The static preload to which the component part is subjected is adjusted only once, at the start of a test.

Resonance Drive

The resonance drive, shown in Fig. 4,

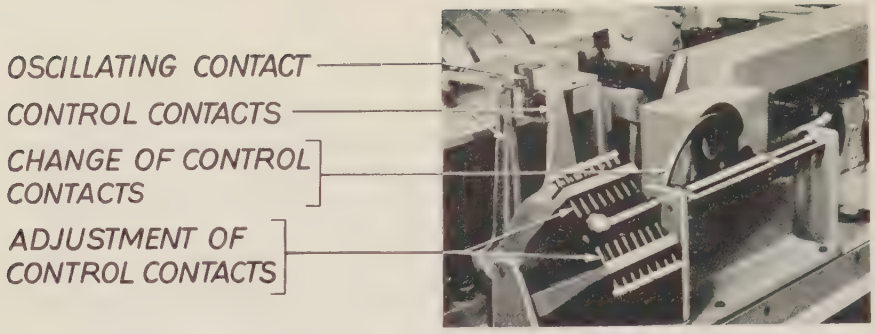


Fig. 6—The amplitudes of the loads generated by the testing machine are simultaneously adjusted for each step with the aid of automatic controls. This figure shows the adjustment mechanism for the automatic controls, control contacts, and the oscillating contact. The oscillating contact is picked up by the control contacts. This action generates control impulses for the adjustment of the load amplitude. When switching from one step to another the corresponding control contacts are changed automatically. The control contacts are adjusted at the start of a test for each step until the desired load amplitude is reached.

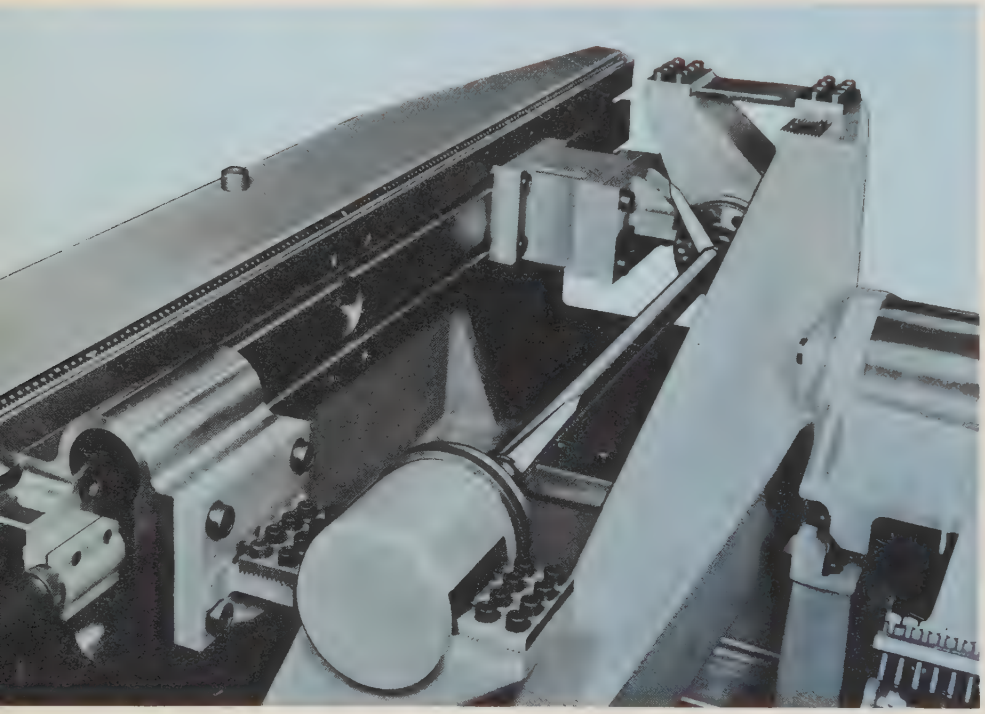


Fig. 7—View of a rear-axle shaft undergoing an endurance test. The shaft is being tested for torsional stress and is held in the machine with the aid of a special twisting fixture. The amplitudes of the loads which the shaft is subjected to are read optically on the dynamometer (left foreground).

is used to generate the smaller and medium loads having a high number of load cycles. This particular drive excites a spring-mass system which is held closely below the natural frequency by means of a rotating unbalance. The test frequency is 800 cpm to 2,000 cpm, depending on the rigidity of the component part being tested. The maximum test stroke when resonance drive is used is ± 32 mm (1.26 in.) for a testing machine with a capacity of 20,000 lb.

Hydraulic Drive

The endurance-testing machine's hydraulic slow drive, along with an enlargement of the machine's hydraulic cylinder, is shown in Fig. 5. The hydraulic slow drive, used to generate the loads having a small number of load cycles, has a test frequency of approximately 4 cpm. The maximum test stroke for the hydraulic slow drive is ± 50 mm (1.97 in.). The hydraulic cylinder of the testing machine serves the purpose of acting as a gripping device or a hydraulic clutch and as a low-frequency drive or alternately-operating cylinder. The hydraulic cylinder has, adjacent to its body, a swinging member which is excited either by a resonance drive at high frequency or actuated by the hydraulic cylinder at low frequencies. The hydraulic cylinder contains two pistons, one of solid-rod construction and the other of hollow-rod construction. Both of the pistons are flanged at their ends. When the endurance-testing machine is changed from high- to low-frequency operation, the resonance drive is switched off and fluid is pressed between the two pistons. When the two pistons are spread apart, the bottom plate of the swinging member is gripped by the flanges of the pistons. Hydraulic pressure is then applied to the end chambers of both pistons. This action serves to impart a reciprocating motion to both pistons as one unit and then to the swinging member.

At the start of an endurance test, the amplitudes of the loads are simultaneously adjusted for each step with the aid of automatic controls. Fig. 6 shows a view of the adjustment mechanism for the automatic controls, control contacts, and the oscillating contact. The oscillating contact is picked up by the control contacts. This action generates the control impulses for the adjustment of the load amplitude. When switching from one step to another, the corresponding control contacts are changed automatically. The control contacts are adjusted at the start of the test for each step until the desired load amplitude is reached. The load amplitude is read optically on a dynamometer which is shown in Fig. 7.

Summary

The results of tests which have been performed to date on component parts indicate that endurance tests can be performed successfully by the machine. The testing time has been reduced to a fraction of that normally encountered for this type of work. As an example, the rear-axle shaft of a vehicle is stressed by the machine in the same way as it would be when driven on the road, but the test speed of the machine is such that the shaft, in one hour, is subjected to strains corresponding to a distance of 400 km (249 miles). Any particular type of stress to which the component part is actually subjected, such as torsional or bending, can be duplicated by the machine. The machine greatly aids in investigating the mechanism of wear by showing the nature of failure. With this aid, engineers are able to improve their designs of component parts.

The Body Draftsman's Function —to Design for Mass Production

By ALFRED S. GREIF and
FRANCIS E. SMITH
Fisher Body Division

The drafting function is a prerequisite to mass production and assured interchangeability of parts. Here, the men on the boards translate designs of engineers and stylists into a precise universal language which leaves nothing open to doubt. In the automotive-body drafting field these men are moving away from pencil and ink on conventional vellum and tracing cloth for complicated die parts, to even more precise methods and materials by scribing their language on a white paint film hardened onto aluminum plates. A foremost requirement is that people in many states and lands be able to use the body-draftsman's information, and the results of each man's work must blend precisely with every other human contribution concerned with getting a new body into production. Body drafting has developed techniques geared to the dynamic automobile industry. An understanding of its procedures and functions cannot fail to promote an appreciation of body drafting's contribution to the automotive age.

No dimensions necessary: a Detroit curve is reproduced alike in Atlanta or Kansas City

THE term *body drafting* is so commonplace that it fails to convey the magnitude and romance of its operation. Actually, it is the expression of ideas and information in drawing and template form which makes possible the production of automobile bodies.

At the Fisher Body Division of General Motors, drafting, designing, and engineering are interwoven into a co-ordinated effort. Just what body drafting means is best understood by seeing what it does in the normal sequence of its operation.

Before the drafting, which is related directly to the volume production of a body, can be initiated, there must be creative design or styling. Even before a new body design is released by the stylists, it is studied for practicability of shape and structure by body-design engineers and tooling and production-planning specialists. Their studies determine whether the shapes can be made and how the body can be sectioned into individual stampings so that welds are advantageously located. Pillar sizes are evaluated for strength, utility, and fabrication methods; the windshield and backlight glass is studied for problems peculiar to the making and installation of such glass; surfaces and shapes, such as rear body panels, are studied for interchangeability with companion body styles; ornamental molding designs and applications are investigated in the light of possible production methods. These and numerous other factors are considered to insure the ultimate design of features which will lend themselves to practical manufacture and economy.

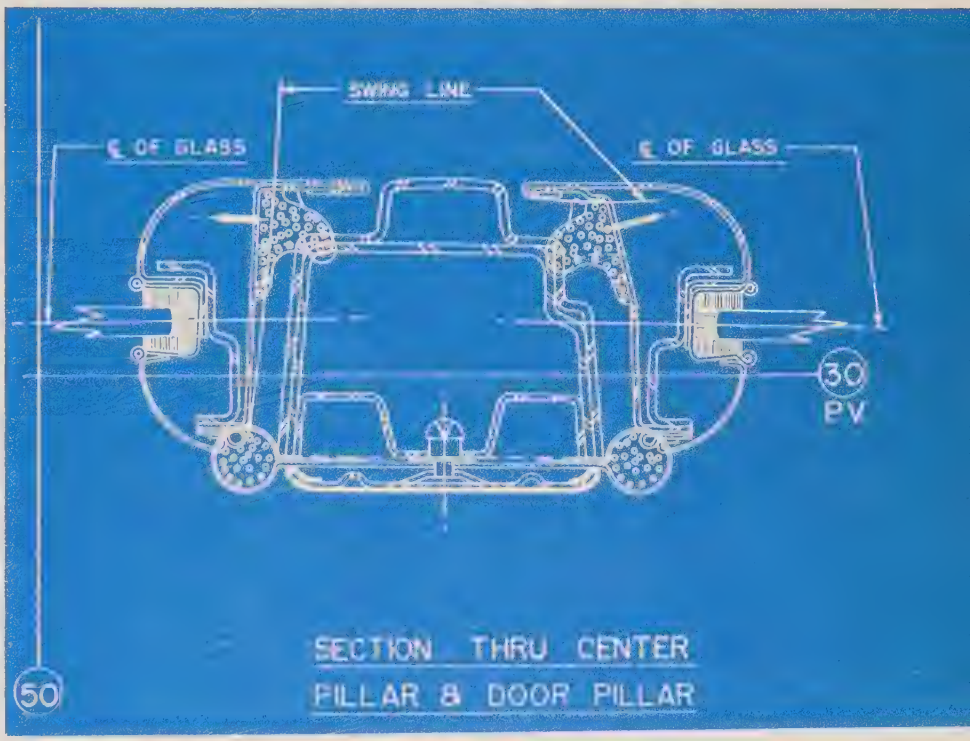


Fig. 1—Numerous typical sections, such as this section through a right-hand center pillar, are drawn during the period when advance-styling drawings are translated into advance designs. Preliminary layout work enables finalizing the design and its completion clears the way to make schedules which will meet car-production dates.

Because the body draftsman must translate this visualization of the designer and stylist into a functional and attractive car body which can be mass produced, he must have an understanding and appreciation of the engineering and styling functions which precede his contributions, and of the tooling and production functions which follow.

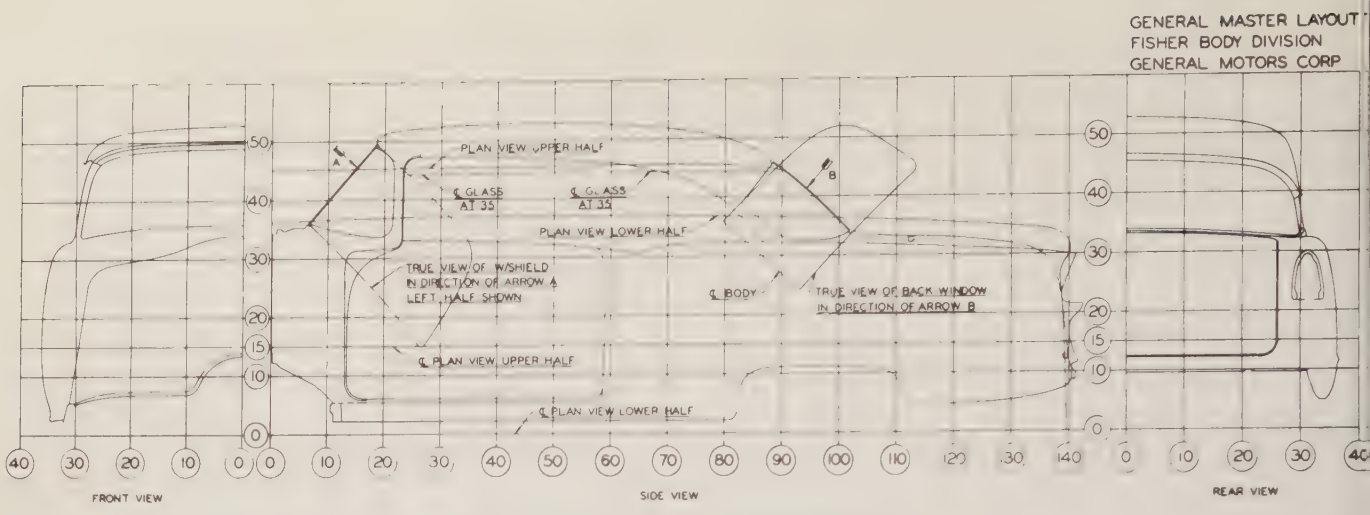

GENERAL MASTER LAYOUT
FISHER BODY DIVISION
GENERAL MOTORS CORP
PLAN VIEW UPPER HALF
℄ GLASS AT 35
℄ GLASS AT 35
PLAN VIEW LOWER HALF
TRUE VIEW OF W/SHIELD IN DIRECTION OF ARROW A LEFT HALF SHOWN
℄ BODY
TRUE VIEW OF BACK WINDOW IN DIRECTION OF ARROW B
℄ PLAN VIEW UPPER HALF
℄ PLAN VIEW LOWER HALF
FRONT VIEW
SIDE VIEW
REAR VIEW

Fig. 2—A major key to interchangeability of parts, even though produced thousands of miles apart, is the full-size master draft scribed onto 20 coats of flat white paint sprayed on aluminum panels, ordinarily 62 in. by 168 in. Information for detail drawings may be extracted from the master draft, as required. Data for die plates and templates also may be extracted. The master-draft surface is divided into grids by horizontally and vertically scribed lines 5 in. apart. These lines are numbered for reference purposes.

Body Drafting

A new program is started by obtaining advance styling drawings so that preliminary layout (*spade*) work can be done in developing advance designs and typical sections. These typical sections are drawings of a constant section or feature of the structure of a body showing the relation of each part to the other. When approved, the typical sections form the basis for the design of the complete body. Therefore, experience and sound judgment are essential when developing these drawings. This work is of utmost importance in clearing the way for the maintenance of established working-schedule dates. Fig. 1 is a typical section taken through a right-hand center pillar.

The styling drawing is made with sufficient detail and accuracy to establish the design and to permit the handmaking of fibre-glass bodies for appearance purposes. However, for production purposes, extreme three-dimensional accuracy must be developed for every sweep, contour, and detail. Just as a rough diamond requires cutting, grinding, bruting, and polishing, so a body draft for production use must be worked out meticulously.

The body-drafting task is such a large one that at Fisher Body it is divided into sections. In this way, a new design can be attacked from several directions at once. Instead of making one complete master draft of the whole automobile body, it is divided into four major sections, as follows:

- Front ends, underbodies, dashes, and instrument panels
- Doors and center pillars
- Rear ends, rear quarters, rear seats, and roofs
- Front seats.

Complete drafting and engineering personnel are set up as departments to handle each of these four major sections.

A new program begins by laying out the surface of the outside of a body. This surfacing starts on the same date in the first three Departments mentioned above. The *front-end master layout* is started by working from the plan-view centerline of the body outboard toward the body pillar. The *rear-end, rear-quarter, and roof master layout* is also started at the plan-view centerline of the body and surfaced in an outboard direction. The Door Department develops the door surface and, in addition, is responsible for all surfaces adjacent to the door openings. The surface-development work of the other Departments must blend into the surfaces developed by the Door Department. In addition to the door surface, the adjacent surface, and the door-opening rabbets, the Door Department is further charged with the responsibility of co-ordinating molding treatments.

The Front End Department is responsible for the layout and design of the tie-in between the front end of the body and the forward portion of the roof. Co-ordination must be worked out with the GM car-producing Divisions (Chevrolet Motor, Pontiac Motor, Oldsmobile, Buick Motor, and Cadillac Motor Car) for all instruments, accessories, and fitting metal surfaces. This involves a great amount of liaison work, especially on the dash, instrument panel, and underbody.

In a similar manner, the Department handling the rear end, the rear quarter, the rear seat, and the roof must work out its surfaces and tie them into the surfaces being worked out by the Door and Front End Departments.

After the outer shell of the body has been surfaced, layout begins on the inner surface, hardware, reinforcements, and seats.

All designs are reviewed with die and production-engineering personnel to be sure they can be economically and efficiently produced. If cost is a deciding factor in choosing between different designs, a cost study is made.

While the layout work is progressing on the master drafts, design problems are continually arising. To aid in solving these design problems, various methods of showing the structural and mechanical features are improvised in wooden, metal, plastic, or clay models. To check accessibility and assembly methods, portions of the new body are made up in wood or clay. Current model cars may be reworked for observation or test performance—for example, the trial of a new windshield wiper.

Fundamentally, drafting is mechanical drawing. However, in the field of body work, drafting reaches the ultimate in accuracy and means of expression. The development of surface lines and the

proper proportion of each detail to the whole body afford a genuine test of the body-draftman's ability.

Body drafting utilizes the principles of descriptive geometry, and a basic understanding of these principles is advantageous in preparing an accurate working draft. All views are made by third-angle projection as in any normal mechanical drawing. The views likewise are called front, plan, and side, and may be supplemented by corresponding auxiliary views.

The fundamental problem of geometry in engineering drawing is to describe exactly the shape of three-dimensional structures by means of drawings. A plane not parallel to a primary plane is not visible in its true view. The true length of a line in such a plane is not visible unless it is the line of intersection with a primary plane. From these principles it may be concluded that, to show a plane in its true view, it must be revolved until it is parallel to a primary plane. By the same reasoning, a line must be revolved until it lies in a primary plane, or in a plane parallel to a primary plane, before its true view is apparent.

When designing certain body areas—such as windshield openings, backlight openings, and deck-lid gutters—sections which are normal to a compound surface must be obtained. These sections are required inasmuch as it is desirable to have a constant section in the area of the pinch-weld flanges around window openings and in the gutter area around the deck lid. A constant section can be obtained only by constructing sections normal to the body surface.

Body draftsmen often work with points as well as with edges. In automobile-body work, there is a limited number of edges which are commonly used in mechanical drawing. In order to control surfaces, points or lines of surfaces are projected between views. Since a curved line is generated by a point moving in a constantly changing direction, sufficient points projected from a given curve will establish a new curve for the second view. The number of points to be projected to establish such a curved line is best determined by experience. If the curve being drawn is relatively flat or straight, points taken every 5 in. or 10 in. are usually satisfactory. In some cases, where there is an abrupt change in contour, it may be necessary to establish points less than ¼ in. apart.

The practices used in designing automobile bodies are closely aligned with the manufacturing practices used in producing the body parts. The large dies necessary in the manufacture of body panels are made not only from detail drawings but also from additional information supplied from an actual-size wooden model, usually called a *die model*. The sequence of building the body is reflected in assembly drawings.

Master Drafts

All lines which eventually describe the appearance of an automobile body are portrayed full-size on a drawing called the master draft. Since paper and cloth are affected by humidity, temperature, and age, master drafts are made on stable metal plates. Aluminum is preferred for these plates because of its lightness and its resistance to corrosion. The plate stock is normally 0.064-in., 3SH aluminum, ½ hard and is prepared with 20 coats of flat white paint having a minimum thickness of 0.008 in. Drafts are scribed with vertical and horizontal grid lines which are very accurately spaced 5 in. apart. These grid lines promote precision by minimizing errors caused by expansion and contraction of the metal plate, however slight this may be. Errors in scaling also are eliminated, since any point on the draft can be located by measuring its relationship to the nearest grid lines.

The importance of accuracy in scribing the vertical and horizontal lines cannot be overemphasized. There have been many methods developed for scribing and erecting the inch lines or grid pattern; very few, however, produce the accuracy required in modern automotive work. The latest method, proved in use over several years, is a photomechanical process which produces identical patterns on successive plates. This method has consistently demonstrated an accuracy of ±0.003 in. over a panel of 14 ft, showing no accumulated error. Using this pattern, 30° grooves (60° included angle), 0.004 in. deep, are cut into the paint on the plate so that the lines are never obliterated.

The zero or base lines which ultimately determine the relationship of the 5-in. lines to the body design are usually standardized as follows:

- Points in a horizontal plane are established in reference to a vertical zero line, which represents the front of the dash-panel assembly.
- Points in a vertical plane are related to a horizontal line which represents the main top of the chassis frame. The main top-of-frame line is determined jointly by the chassis designer and the body engineer.
- Points pertaining to the width of the body are established by their relationship to the centerline of the body, labeled as the third zero-inch line.

The usual dimensions of the full-size master draft are 62 in. by 168 in. Master drafts wider than 62 in. are not considered practical; the drafting boards would require excessive space, and it would be inconvenient for the draftsman to work the full area of the board. It is often necessary to superimpose views in order to conserve space. In the majority of the views, the right-hand side of the body is symmetrically opposite the left-hand side. Whenever the right and left sides are not symmetrically opposite and the difference in views is slight, this difference is usually shown as an overlay on the right-hand view. When the left- and right-hand sides of a panel differ greatly, as in the instrument panel, it is essential that both sides be shown in all views.

Complete drawings of automobile bodies always present the body with the front of the side view, or elevation, toward the left-hand side of the draft. The 15-in. horizontal line is commonly used for the centerline of the top, or plan view. Fig. 2 illustrates the basic outlines and the placement of views on a general master layout (*draft*).

Coinciding with the development work-out of the master drafts is an extensive amount of experimental layout work. This is sometimes the original conception of a design or the placement of units with due consideration given to clearances. These experimental layouts are not production drawings but are a basis from which production drawings are eventually made. A good layout drawing embodies sufficient basic reference lines and tell-tale sections to make it understandable without considerable explanation.

There is no fixed rule as to the number of master drafts to be made for any problem; this is determined by the design

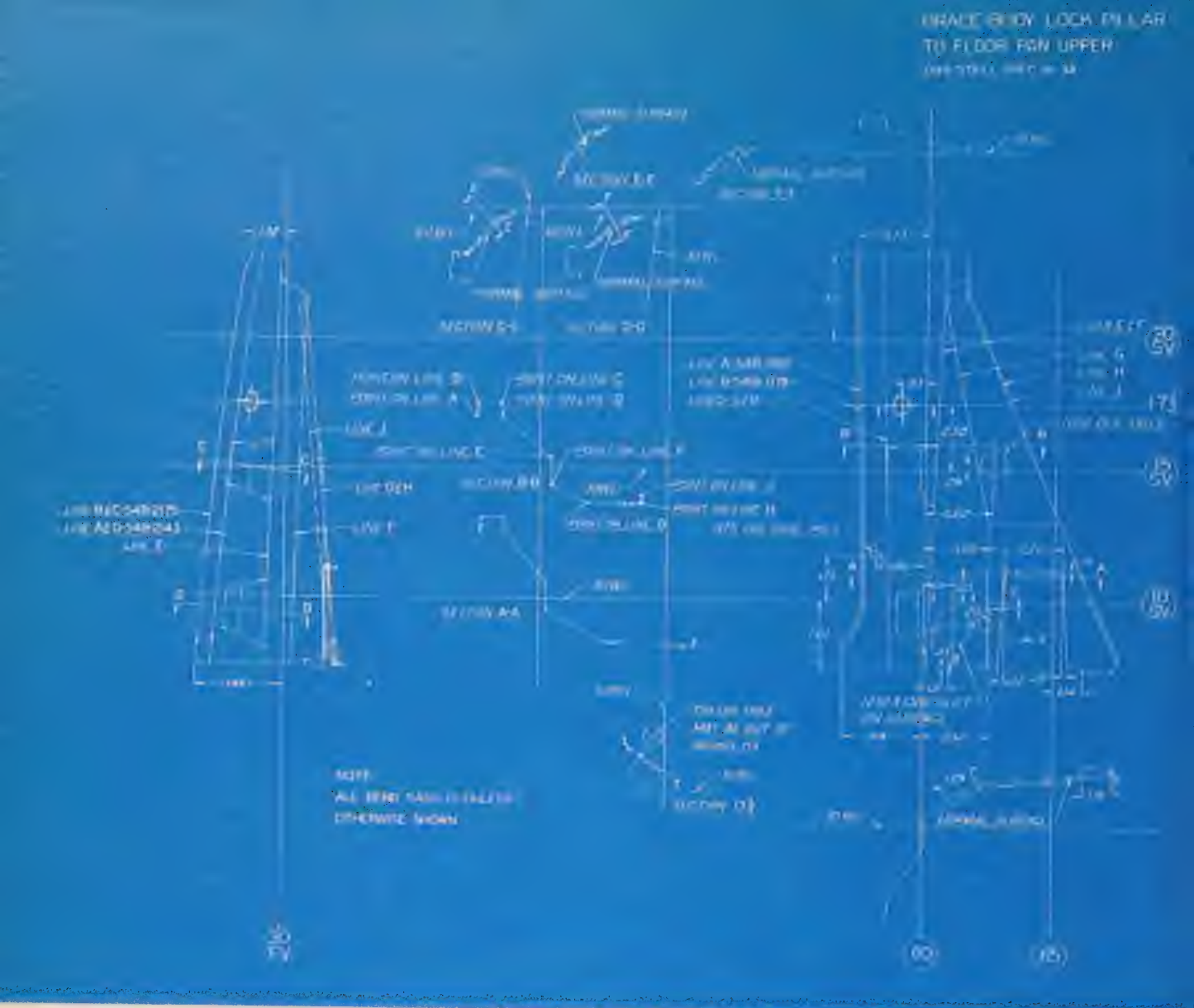


Fig. 3—Die models, dies, fixtures, and parts for auto bodies may be supplied by firms geographically far apart. It would be impractical to provide drawings with sufficient data for certain contours, such as for surfaces having compound curves. An often-used short-cut is the *die plate*, such as this one of a pillar brace, which is drawn full-size to the inside of metal on white-painted sheet aluminum stock. Die plates may be supplemented by aluminum templates. A die model is always made.

of the particular body and the problems of each individual drafting group. Some master drafts which are required to complete a body program include master-layout drawings of the rear-compartment lid and gutter, rear quarter window, back window, front-end hardware, dash panel, instrument panel, front-seat door, and underbody. Every part, from the smallest screw to the large roof panel, must appear on one of these master drafts. Moving parts, such as window regulators, are shown in up and down positions and any other critical (minimum-clearance) positions.

Detail Drawings and Die Plates

Individual parts are detailed on separate drawings from each of these master drafts, the majority of them being drawn on tracing cloth, showing all necessary dimensions. Die-made parts of any complexity are detailed on a *die plate* (a full-size detail drawing prepared on white-painted, sheet aluminum stock). The die plate provides all surface and contour lines necessary to fabricate the part.

It is impractical to dimension these drawings completely due to the complexity of the surfaces of the parts and, accordingly, they are supplemented by aluminum templates. However, typical sections, hole sizes, and locations are usually dimensioned. The amount of dimensioning required is determined by the Checking Department. Accuracy must be maintained in the construction of the surface lines as scaling of the drawing is necessary for dimensional information.

This fully developed, accurate drawing simplifies construction of die models, dies, and fixtures. It provides a reliable means of insuring an accurate understanding of the part by die, fixture, and model makers. Except for molding and ornamental parts, all die plates are drawn to show the inside surface of metal. This helps in making the die model which, in turn, is an aid in building the *die punch* and is especially helpful when

the punch can be *Kellered* (a profile duplicating process). A plaster cast of the die model is used in making the female half of the die and the fit with the punch is developed to suit. Fig. 3 shows a typical die plate.

Die plates show the outside surface of metal for moldings and ornamental parts for here the external appearance is most important (surface contour—design lines and co-ordination with related parts). Die models made to these drawings depict the outside surface of metal. To insure proper interpretation of the fit requirements of the part and to provide a means of inspection, the drawing and engineering information are augmented by a checking fixture.

Surfaces of the body on which moldings or ornaments must fit are considered to be critical areas and a note to this effect is shown on the part drawings. To aid in building tools and checking fixtures, plastic surface blocks are made by molding them from the critical areas of the body die models.

Templates

Templates are used extensively in body drafting. As soon as the surface of the body is worked out on a master draft, templates are made for approximately every 10 in. of surface (more or less, depending on the amount of change of surface). They are prepared for all outlines, such as door windows, deck lids, and fenders. They range in size from the large section of a roof panel to a cross section of a rubber weatherstrip. These templates are flat and are normally made from 0.064-in. aluminum sheet stock. Identifying information and a number are placed on each template, these same numbers being added to the master drafts at the location where the template was cut.

When a die plate is being made, the draftsman uses the same templates for drawing the main lines. The template numbers are again called out on the die plate and this same process is repeated when a tracing is made of the plate. Thus, all blueprints that are made from the tracing call out the template numbers.

As the die model is started, duplicates of each template are available to the model makers. Similarly, templates are available for building an inspection fixture or checking a finished part.

Templates serve an equally important role in maintaining consistency and uniformity of body surfaces between companion body styles, such as two- and four-door sedans. They are also used to co-ordinate adjacent surfaces from one master draft to another in a simple and accurate manner.

Of course, templates must be kept up-to-date with any change occurring on a master draft, and this is done with precision and dispatch.

Fig. 4—Drafting, designing, and engineering are interwoven into a co-ordinated effort at Fisher Body Division. A number of unique methods are used by body draftsmen to transmit the ideas and information from the stylist's design to drawings from which automotive bodies are produced in volume.

Assembly and Installation Drawings

Whereas a detail drawing is needed in order to make each individual part, assembly and installation drawings are required for putting the parts together. Assembly drawings provide the necessary welding information and attaching parts required to join two or more components. Installation drawings provide all necessary dimensions and information required for the installation of parts in their final position in the body and, in addition, show reference dimensions which will be useful in subsequent engineering, plant fabrication, and inspection. Because the amount of information is so extensive, some of these drawings are twice as long as a completed automobile.

Supplementing the assembly drawings is information on specialized items such as electrical wiring, cements, sealers, weldments, and soft trim. These drawings are prepared in graphic illustration (perspective) form for maximum clarity.

Summary

In drafting, there must be order and regulations or standards. Fisher Body provides each draftsman with an engineering manual containing a set of basic drafting standards for his individual guidance.

To those in the body-drafting business, the work is both intriguing and rewarding (Fig. 4). It offers a challenge to individual capability and a feeling of gratification when the end product is acclaimed. In a field of endeavor so broad that it spans design, engineering, and development, the body draftsman is truly in the front seat of our present-day world on wheels.

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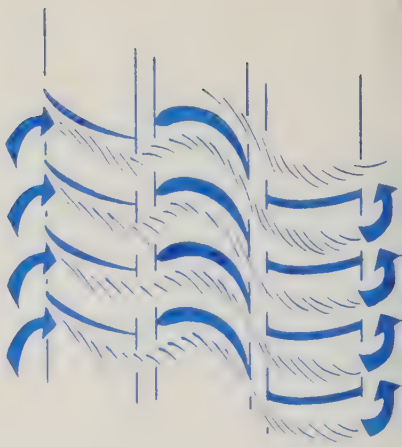
Operating Principles of Buick's Twin-Turbine Dynaflow Torque Converter



The design requirements placed on automatic transmissions are many and varied and the transmission engineer, in evaluating the requirements, develops a final design which often embodies the optimum compromise of the requirements. Such has been the case in the development of the hydro-kinetic drive member of Buick's twin-turbine Dynaflow transmission. To satisfy the requirements as fully as possible, to effectively utilize the engine's power, and to provide an automatic transmission acceptable to the car-buying public, the simple three-element torque converter has been modified and expanded to take full advantage of its infinitely variable torque-multiplying ability. To further increase the efficiency of the unit when operating at cruising speed conditions, provisions have been made in its design so that the units function in a manner similar to a fluid coupling.

THE automotive transmission is required to compensate for the shortcomings of the internal-combustion engine. The internal-combustion engine, as it is known today, cannot run below approximately 400 rpm without stalling; develops relatively little torque at low speed, when torque demand is greatest to obtain good car acceleration; and cannot practicably be made to run counterclockwise to reverse the motion of the vehicle.

For a transmission to overcome the undesirable characteristics of the internal-combustion engine there are certain requirements which must be inherent in its design, such as:

- Prevent the engine from stalling when the car speed is low or zero
- Enable the engine to operate at a higher speed where it develops more power while the transmission multiplies engine torque for better acceleration
- Reverse the rotation of the drive shaft, using a gear train to provide a means for reversing the vehicle motion.

These are the essential requirements of an automotive transmission. There also are many secondary requirements expected, such as:

- Smooth, easy, and noiseless operation
- Aid in giving maximum car performance and best fuel economy
- Minimum manipulation of controls by the driver
- Smallest size, weight, and cost of manufacture.

The transmission engineer is confronted with the problem of evaluating these requirements in such a manner that the final transmission design will embody the optimum compromise of the requirements. Combined with these technical requirements is the absolute essential that the design must also be acceptable to the average driver.

In the past few years there has been an increased preference by the car-buying public for automatic transmissions over the conventional, non-automatic, sliding-gear, three-speed synchromesh transmission. As a result, the transmission engineer has concentrated engineering effort and development work mainly on the automatic transmission and its three main component members—the hydro-kinetic drive, planetary gears, and hydraulic controls. An automatic transmission can be efficient only if each of its main component members effectively carries out the design requirements. A knowledge, therefore, of the fundamental engineering principles and operating characteristics of each main component member is essential.

In the case of Buick's twin-turbine Dynaflow transmission, the basic engineering principles and operating characteristics of the hydro-kinetic drive member, which is a torque converter, have been known for some 45 years. It remained for the transmission engineer to apply the basic engineering principles of the torque converter toward the development of an automatic transmission which would employ its infinitely variable torque-multiplying ability and complete smoothness of operation characteristics.

Another type of hydro-kinetic drive—the fluid coupling—also had operating characteristics which were well-established and which were suitable for automatic transmission application. The fluid coupling's characteristic to slip only a small amount at high rotative speed and transfer little torque were factors taken into consideration when the hydro-kinetic drive component member of the twin-turbine Dynaflow transmission was developed.

The torque converter and the fluid coupling, therefore, each possessed characteristics highly desirable for automatic transmission application. By utilizing the basic engineering principles and operating characteristics of the torque converter, by modifying its basic design to include a second turbine, and by designing the overall unit to function as a fluid coupling when operating at cruising speeds, a highly effective hydro-kinetic drive component member of an automatic transmission was developed.

The operation of the hydro-kinetic drive member, or torque converter, portion of the twin-turbine Dynaflow transmission can best be explained by the use of vector diagrams which aid in showing how the driving and reaction torques and forces change in magnitude and direction as the converter operates from start to cruising speed conditions. As a way of introduction, however, a few of the principles of the fluid coupling and basic torque converter will be explained to establish a background for the reasons behind the hydro-kinetic drive's operation.

Operating Principles of a Fluid Coupling

A spinning flywheel has stored up energy and, when stopped, exerts a force

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Motor
Division

Basic torque converter modified to give unique hydraulic drive unit

on the mechanism tending to stop its rotation. Conversely, a force must be exerted against the flywheel to get it up to speed after it has been stopped.

A fluid coupling, with an engine driving its input member and its output member stalled or stationary, is a direct equivalent of the spinning flywheel principle.

To illustrate this principle, assume that a fluid coupling, driven by a car engine, has its input member turning at ,000 rpm and its output member stalled Fig. 1). The input member represents simple centrifugal pump which picks luid up at a small diameter and makes it pin along with its straight blades. Due o centrifugal force the fluid is sent out adially and leaves the input member at large diameter in the form of a spinning ywheel rim—a flywheel rim composed f fluid.

The energy contained in this spinning ywheel rim of fluid is derived from the ngine. Because the output member of he fluid coupling is stationary, a force s exerted on its straight blades as the pinning flywheel rim of fluid is stopped. he force exerted depends on the rate t which the spinning flywheel rim of uid is stopped and its mean diameter nd weight. The fluid then flows from he large diameter to the small diameter f the output member, having an inward adial movement and no spinning movement. When the fluid leaves the small iameter of the output member it e-enters the input member and repeats he cycle.

The energy output of a spinning flywheel can be explained if two flywheels re assumed running at 1,000 rpm—each eighing the same but having different

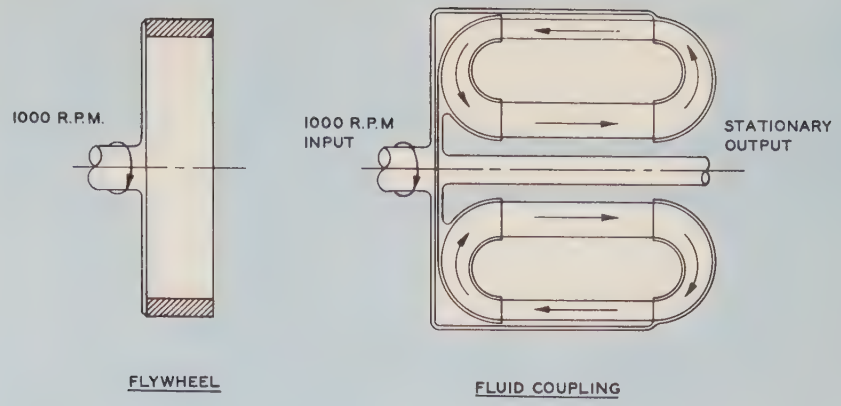


Fig. 1—A spinning flywheel, which exerts force on a mechanism stopping its rotation, parallels the operation of a fluid coupling which has its input member rotating and its output member stalled or stationary. The rotating input member acts as a centrifugal pump and the fluid, which enters the input member at a small diameter, leaves the input member radially at a large diameter in the form of a spinning flywheel rim which, when striking the blades of the stationary output member, exerts a force which imparts rotative motion.

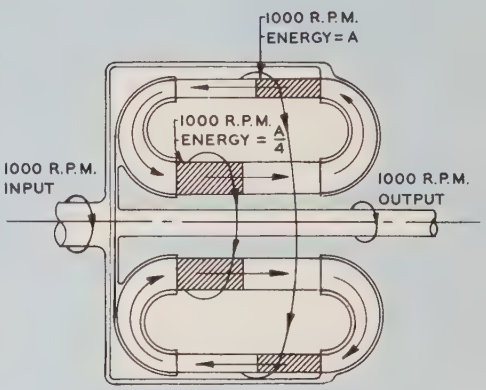


Fig. 2—The energy contained in the fluid as it leaves the fluid coupling output member is one-fourth the energy contained in the fluid when entering the output member. The difference, or three-fourths of the total energy contained in the fluid, is absorbed by the output member and used as the driving force of the fluid coupling.

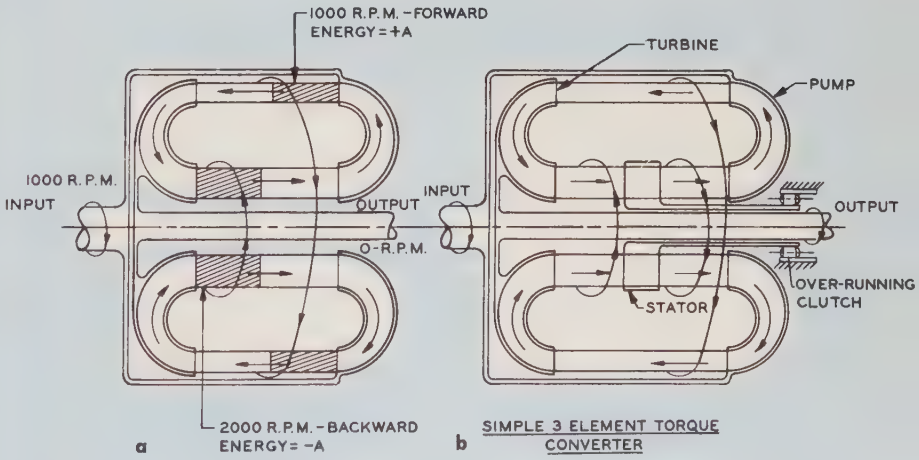


Fig. 3—When the straight blades of the fluid coupling output member are replaced by blades that are strongly curved backward, 3a, the fluid leaves the output member with a backward spinning motion and causes a greater force to be exerted on the blades of the output member. The backward spinning motion of the fluid is opposite to the rotative direction of the input member it is to enter and if allowed to impinge directly on the input member blades requires an appreciable amount of energy from the engine to stop the backward spinning motion. In order that this might not happen, a stationary member called the stator, 3b, is interposed between the input—or pump—and output—or turbine—members and reverses the backward spinning motion of the fluid so that it has the same direction of rotation as the pump it enters. Addition of the stator changes the fluid coupling to a torque converter. The reactive force on the stator establishes the amount of torque multiplication which the converter unit develops.

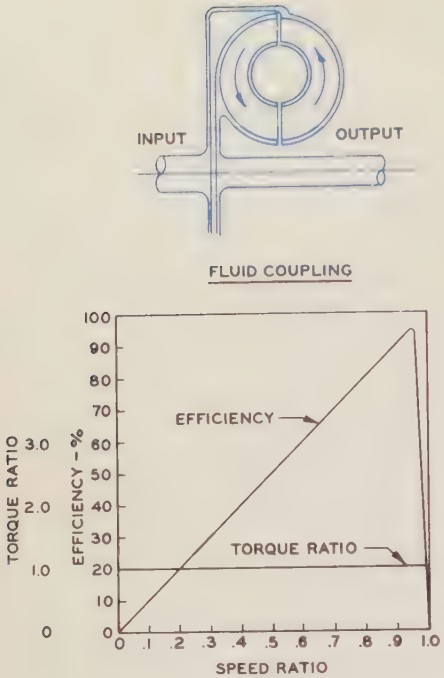


Fig. 4—Typical fluid coupling torque ratio and efficiency curves. The torque ratio is always 1 to 1 which points out that the fluid coupling does not multiply the input torque. The efficiency of the coupling is always inversely proportional to the slip between the input and output members. As the relative speed of the two members approaches 1 to 1 the efficiency drops off to zero which indicates that when both members rotate at the same speed no torque is transferred.

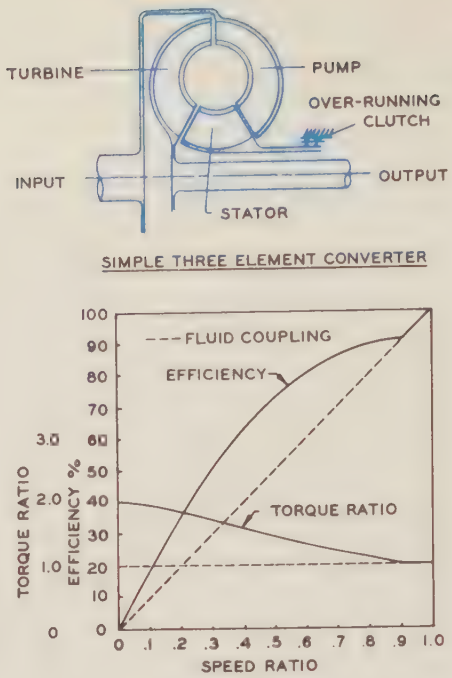


Fig. 5—Typical torque ratio and efficiency curves of a simple three-element torque converter superimposed on similar curves for a fluid coupling. The torque ratio curve points out that the torque converter can multiply torque due to the addition of the stator. The efficiency of the torque converter rises faster than the efficiency of a fluid coupling, peaks, and falls off until reaching the fluid coupling efficiency curve. At this point the stator, by virtue of its overrunning clutch arrangement, free wheels and the entire torque converter unit operates as a fluid coupling.

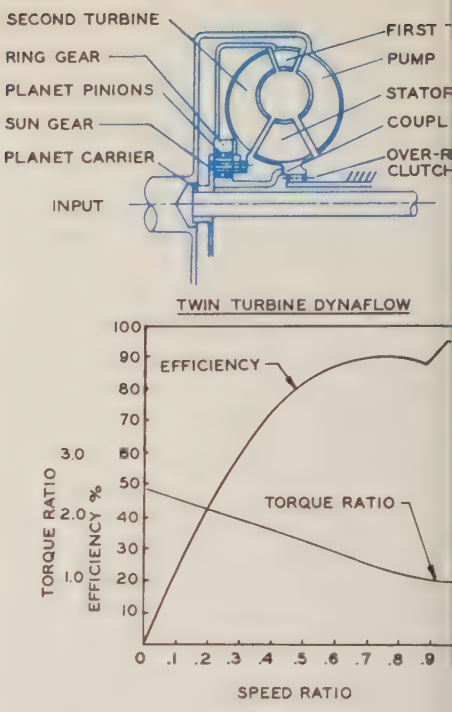


Fig. 6—Torque ratio and efficiency curves for Buick twin-turbine Dynaflow torque converter. modification of the basic three-element torque verter to include two turbines, or output mem increases the efficiency and torque output considera

mean diameters. If the diameter of the larger flywheel is twice the diameter of the smaller flywheel it will have four times the inertia of the smaller flywheel, although no heavier in total weight. In other words—the energy contained in the larger flywheel by virtue of its larger size is four times greater than that in the smaller flywheel, although both weigh the same and run at the same speed. If both flywheels were to have the same energy, the smaller one would have to run twice as fast as the larger.

The energy output of a fluid coupling running efficiently at a higher speed parallels the energy output principles of a spinning flywheel. Assume that a fluid coupling has both its input and output members turning at 1,000 rpm (Fig. 2). If a value **A** is assigned to the energy in the fluid as it leaves the input member, the energy of this same fluid as it leaves the output member will be ¼ **A** and the difference, or ¾ **A**, will be absorbed by the output member and used as the driving force of the fluid coupling.

To enable the transfer of power from the input member to the output member, via the medium of flowing fluid, the speed of the driven member must lag the speed of the driving member. If the speed of the driving and driven members were equal, the counter centrifugal forces of the fluid in the driven member would balance the centrifugal forces of the fluid in the driving member. As a result, fluid flow would not take place. The amount of lag between the driving and driven members depends on their speed and the amount of torque being transferred.

Operating Principles of a Simple Three-Element Torque Converter

Fig. 3a shows the fluid coupling which was used as an example in the previous discussion but with the straight blades of the output member replaced by strongly curved blades. Assume, as before, that the input member of the fluid coupling is turning at 1,000 rpm; that the output member is stalled or stationary; and that 100 per cent circulating efficiency exists.

If the entrance to the blades is suc that the fluid is received without splas and if the blades are strongly curve backward so that the fluid, upon exi actually spins backward there result in effect, a backward spinning flywhee rim of fluid. The force acting on th output member, also referred to as th turbine, is obviously much greater tha before, when it had straight blade since it not only has absorbed the energ in stopping the spinning flywheel rim o fluid which entered it but also ha reversed the direction of spinning.

An appreciable amount of energ would be required by the engine to sto the backward spinning flywheel rim o fluid if it were permitted to impinge directly on the blades of the input mem ber, also called the pump. To alleviat this situation, a stationary member called the stator, is interposed (Fig. 3b) The addition of the stator changes th fluid coupling into a simple three element torque converter.

The stator member, which also ha curved blades, reverses again the direc tion of the spinning fluid and causes it t spin in the same direction as the pum it enters. The reactive force on the stato

nember establishes the amount of torque multiplication of the unit and design considerations are such that the output orque must always equal the input orque plus the reaction torque on the tator support. After receiving the fluid rom the stator blades the pump member icks up the fluid and adds energy to it is it passes from the entrance diameter o the exit diameter.

The flowing fluid functions in the ame manner when the turbine member s permitted to rotate. The rate of fluid low decreases as the turbine speed pproaches the pump speed and the orque multiplication decreases at the ame time. It is this characteristic which nables the engine, in conjunction with he torque converter, to supply maximum orque for starting and acceleration at he time when torque demand is greatest. his feature, therefore, satisfies one of he previously mentioned requirements f a transmission.

At cruising speeds the rate of fluid flow hrough the openings between the blades, r the vortex flow, is small but the otary motion of the pump and turbine s high. Under this operating condition he stator forms a very serious obstruction to the flow of fluid and causes the fficiency of the unit to drop as the car peed increases. To prevent this osbtruction, the stator member is mounted on n overruning clutch. This enables the tator to change the direction of fluid ow when needed and to *free wheel* out f the way, or along with the rotary uid flow, when not needed. Under these onditions of cruising speeds, the converter design is such that it functions in manner similar to a fluid coupling.

Torque Ratio and Efficiency Curves

Fig. 4 shows typical fluid coupling orque ratio and efficiency curves. The urves show that the torque ratio is lways 1 to 1, which means that the uid coupling does not multiply the nput torque and functions merely as a orque transmitter. The efficiency curve or the fluid coupling is always inversely roportional to the slip between the two members of the coupling. As the relative peed of the input and output members f the coupling approach 1 to 1 the fficiency falls off to zero because no orque can be transferred.

Fig. 5 shows typical torque ratio and fficiency curves of a torque converter, superimposed on similar curves for a fluid coupling. The curves show that a torque ratio of more than 1 to 1 can be obtained with a torque converter which means that it can multiply torque. The efficiency curve for a torque converter rises faster than for a fluid coupling, peaks, and then falls off until it reaches the fluid coupling curve. At this point the stator member of the torque converter free wheels and the entire unit functions in a manner similar to a fluid coupling.

Fig. 6 shows a portion of the converter section of the twin-turbine Dynaflow transmission along with the unit's torque ratio and efficiency curves. Comparison of Figs. 5 and 6 show the additions that were made to the design of the basic torque converter in affecting the finalized design of the twin-turbine Dynaflow torque converter. A comparison of the two figures also will point out the improvement in efficiency and torque output that the twin-turbine Dynaflow torque converter affords.

Overall Sequence of Operation

Fig. 7 shows a cutaway view of the twin-turbine Dynaflow transmission torque converter which utilizes the torque-multiplying characteristics of a planetary gear set in conjunction with the torque-multiplying ability of a fluid torque converter.

Fig. 8 shows a cutaway view of the complete twin-turbine Dynaflow transmission consisting of the torque converter in conjunction with a planetary gear set and a hydraulically operated transmission necessary to obtain the various ranges—Park, Neutral, Drive, Low, and Reverse.

The converter pump is driven by the car engine and energizes the converter fluid. The first turbine receives the fluid leaving the pump and drives the planetary ring gear through a diaphragm member which is riveted to the ring gear. The second turbine is doweled and bolted to the planet carrier which, in turn, is splined to the converter output shaft. The stator is mounted on an overrunning clutch, which is common to the stator and the planetary sun gear.

The arrangement of the twin-turbine Dynaflow torque converter is unique in that all of the power transferred at low speeds is through the planetary gear set and first turbine. When the car is either starting or climbing a steep hill, the torque demand is greatest and the driving force imparted to the oil acts initially with the greatest force on the first turbine. As the car speed increases, the speed of the first turbine also increases. This causes less pump energy to be absorbed by the first turbine and more pump energy to be imparted to the second turbine. A point is eventually reached where the torque delivered by the first turbine, through the planetary gear set, becomes zero and the second turbine takes over the drive. During this operation sequence the stator automatically redirects the oil which is taken by the pump and redelivered to the turbines. When the second turbine delivers all of the drive, the stator is no longer needed and, by virtue of the overrunning clutch arrangement, free wheels out of the way while the pump and second turbine operate as a fluid coupling.

Driving and Reaction Torques and Forces

Fig. 9 shows the driving and reaction torques and forces which occur in the torque converter during high torque output operation. At stall conditions, the output shaft and the two turbines are stationary. The engine, in driving the converter pump, produces a fluid driving force **P**. The fluid in circulating through the stationary first turbine imparts a force which, in turn, is resisted by force $\mathbf{T}_1$. The fluid passes through the second turbine and then to the stator which redirects its flow and causes a reaction force **S** on the stator. The fluid driving torque **P** plus the stator reaction torque **S** is always equal to the driving torques $\mathbf{T}_1$ plus $\mathbf{T}_2$. During high torque output operation, driving torque $\mathbf{T}_2$ is zero.

The driving torque $\mathbf{T}_1$, when fed into the planetary gear set, is increased by the ratio of 1.6 to 1. The stall torque ratio is finally raised to 2.45 to 1 by the planetary gear set arrangement. This arrangement has the ring gear, which is connected to the first turbine, driving; the sun gear held stationary by the overrunning clutch; and the planet carrier, which is splined to the converter's output shaft, driven by the planet pinion.

Fig. 10 shows the driving and reaction torques and forces which occur during an increase in car speed. The driving force $\mathbf{T}_1$ on the first turbine gradually decreases, along with the stator reaction force **S**, as the driving force $\mathbf{T}_2$ on the second turbine increases. The driving force $\mathbf{T}_2$ is delivered directly to the converter output shaft due to the second

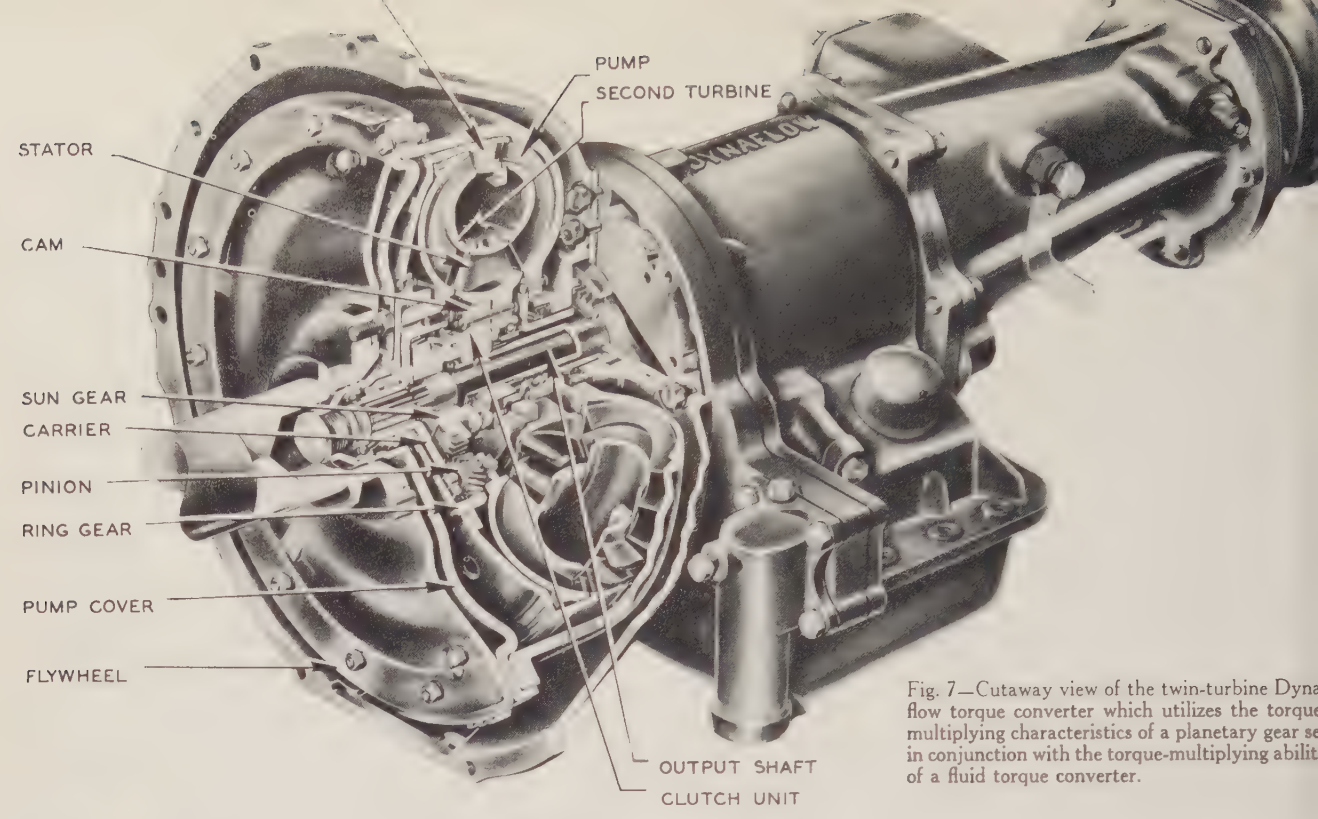


Fig. 7—Cutaway view of the twin-turbine Dyna flow torque converter which utilizes the torque multiplying characteristics of a planetary gear se in conjunction with the torque-multiplying abilit of a fluid torque converter.

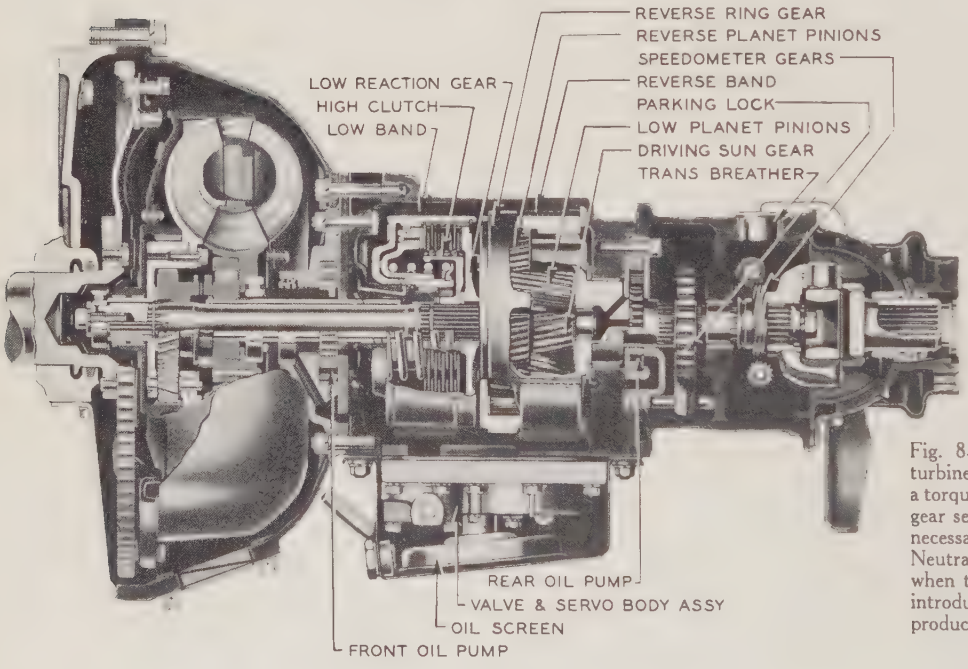


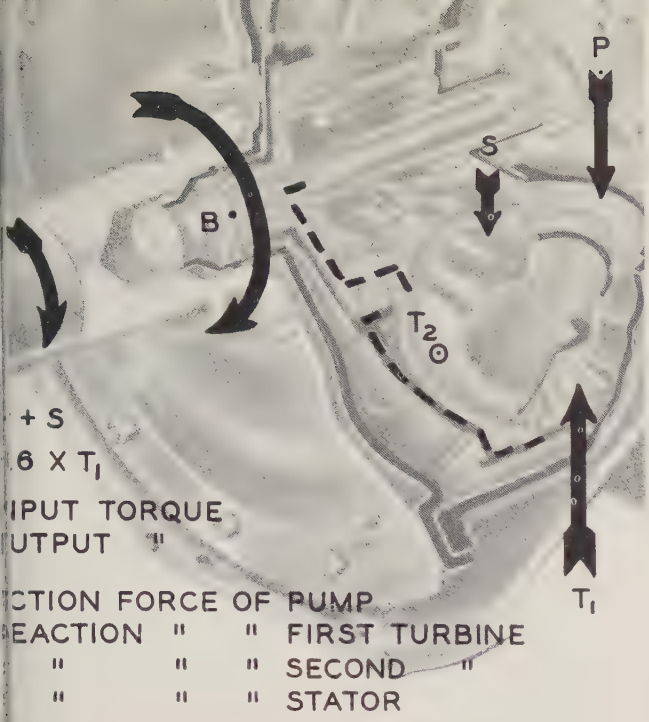
Fig. 8—Cutaway view of the complete twi turbine Dynaflow transmission which consists a torque converter in conjunction with a planeta gear set and hydraulically operated transmissio necessary to obtain the various ranges—Par Neutral, Drive, Low, and Reverse. Since 194 when the Dynaflow automatic transmission w introduced, more than 2,000,000 have be produced.

turbine being secured to the planet carrier which, in turn, is splined to the main shaft. As the car speed continues to increase, the driving force T_2 on the second turbine exceeds the driving force T_1 on the first turbine and the stator reaction force S continues to decrease (Fig. 11).

At cruising speed operation, the first turbine transfers no power due to the driving force T_1 being zero. The total transfer of power comes from the second turbine as driving force T_2 increases to its maximum (Fig. 12). The stator, which takes no reaction, free wheels in a clockwise direction due to its over-running clutch arrangement. At cruising speeds the operation is such that the torque converter no longer multiplies torque and operates, therefore, in a manner similar to a fluid coupling.

How Driving and Reaction Torques and Forces Take Place

The manner in which the driving ar reaction torques and forces take pla can best be illustrated by vector di grams. (The vectors shown are for pu poses of illustration only and do n necessarily represent true values.) T



.Driving and reaction torques and forces which occur in the Dynaflow rbine torque converter during high torque output operation. Fluid force P is produced by the engine in driving the pump. When the rikes the blades of the stationary first turbine a reaction force T_1 is d. The fluid passes through the second turbine and then to the stator edirects the flow and causes a reaction force S on the stator.

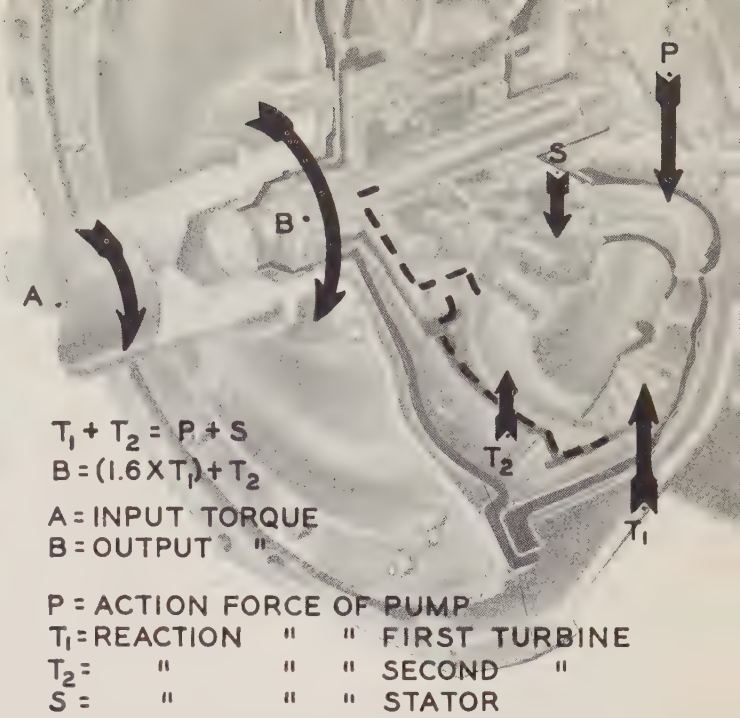
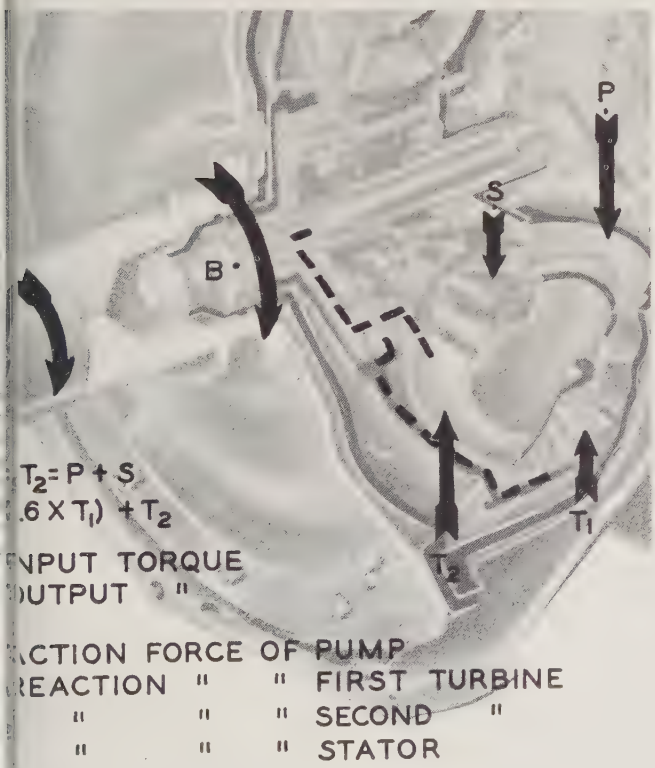


Fig. 10—Driving and reaction torques and forces occurring in the Dynaflow twin-turbine torque converter as an increase in car speed takes place. Driving force T_1 on the first turbine decreases gradually, along with stator reaction force S as the driving force T_2 on the second turbine increases.



—Driving and reaction torques and forces occurring in the twin-Dynaflow torque converter with an increase in car speed approaching speed conditions. Driving force T_2 increases and exceeds driving on the first turbine. It is in this manner that the second turbine takes re and more of the driving power as car speed increases. Stator reaction steadily decreases with an increase in car speed.

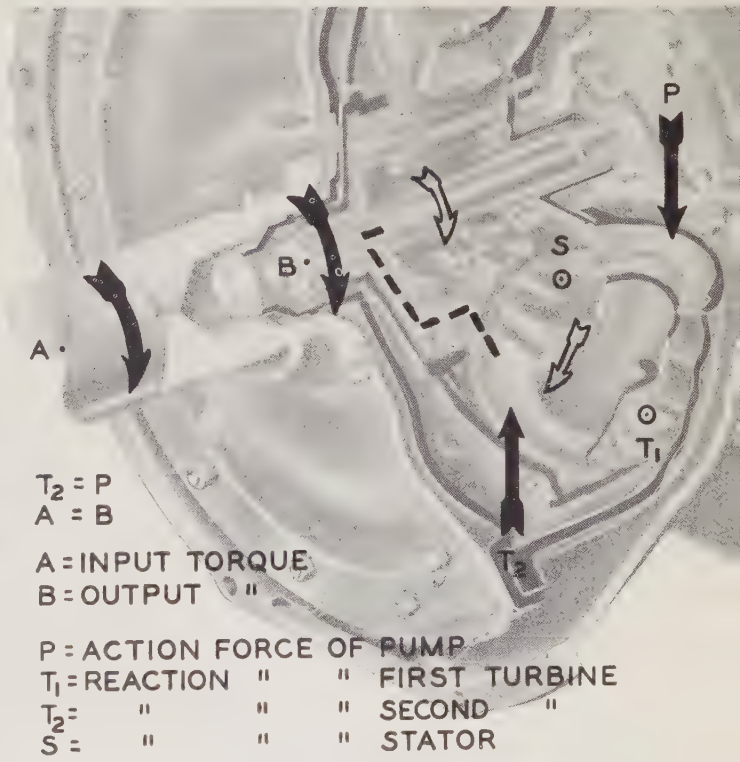


Fig. 12—Driving and reaction torques and forces occurring in the twin-turbine Dynaflow torque converter during cruising speed operation. Driving force T_1 is zero and indicates that the first turbine transfers no power. Driving force T_2 is maximum and indicates that all driving power is received from the second turbine. The stator reaction force S is zero and indicates that the stator is taking no reaction and is free wheeling. The torque converter operation at cruising speeds is such that no torque is being multiplied and the entire unit operates in a manner similar to a fluid coupling.

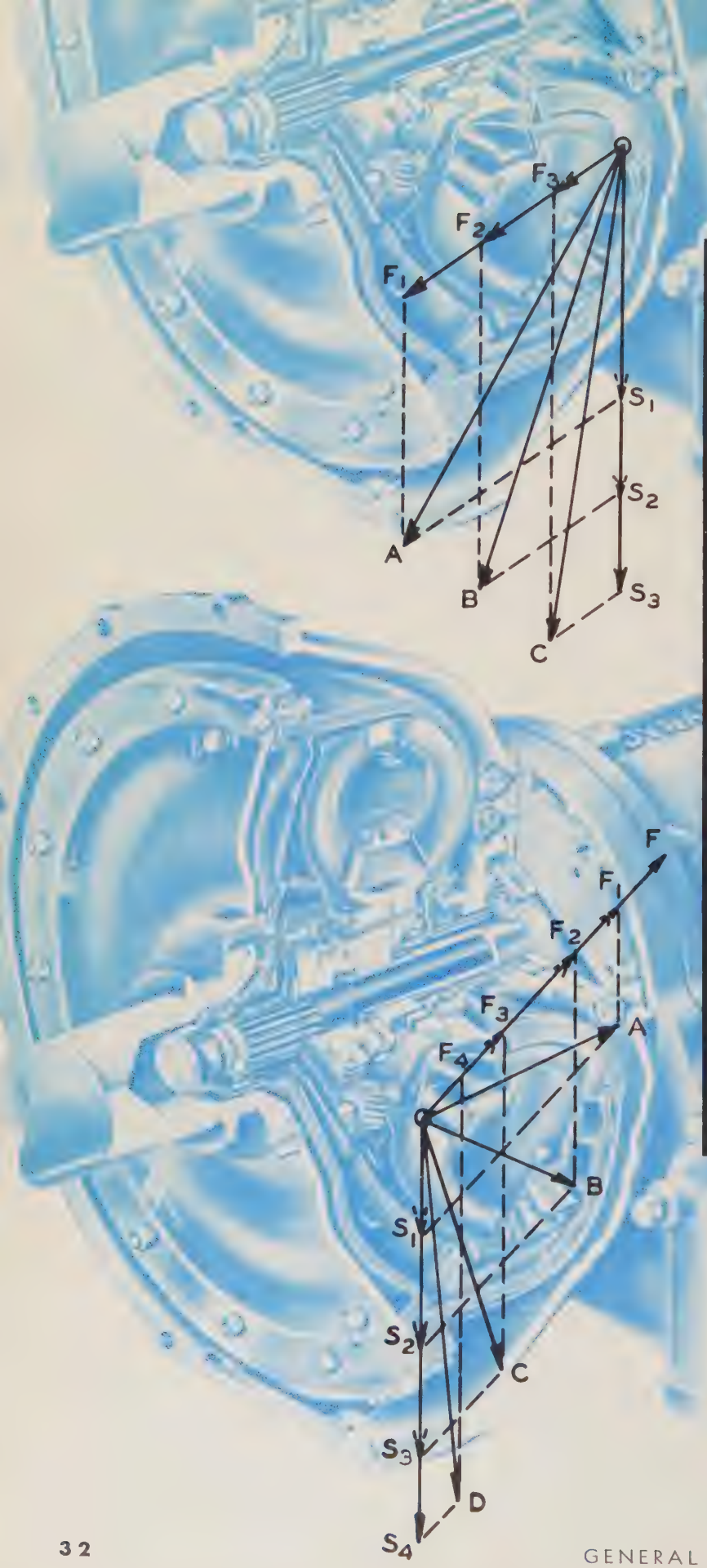
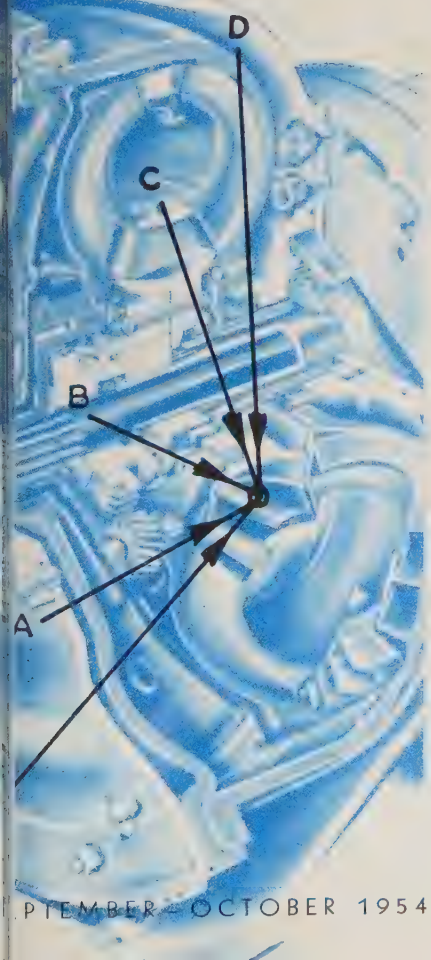


Fig. 13—Vector analysis for the twin-turbine Dynaflow torque converter pump. Because the pump operates like a simple centrifugal pump the absolute velocity of the fluid is the vector sum of the circumferential speed S of the pump blade which drives the fluid plus the linear velocity F of the fluid in relation to the blade. As the pump speed increases and the fluid flow decreases, the vector sum changes in direction and magnitude as shown by vectors A, B, C, and D.

Fig. 14—Vector analysis of the fluid leaving the first turbine blades of the twin-turbine Dynaflow torque converter. The analysis shows the amount of directional change of the fluid as it flows between the pump exit and the first turbine exit and indicates the force imparted to this member. At stall, the turbine speed is zero and the direction of fluid flow is tangent to the exit end of the first turbine blade as shown at F. As the first turbine speed increases, the directional change in the fluid flow is shown by vectors A, B, C, and D. At D the high rotational speed of the turbine causes the fluid to flow between its blades without change in direction. At this point the first turbine delivers no drive and the second turbine blades do all of the driving.

Fig. 15—Vector analysis of the twin-turbine Dynaflow second turbine. The curved blades of the second turbine are designed with an exit diameter smaller than the entrance diameter. This enables the second turbine to extract further energy from the flowing fluid. The linear velocity of the fluid in relation to the second turbine blades is shown at F. The exit fluid flow for the second turbine is shown by vectors A, B, C, and D.

Fig. 16—Vector analysis of the fluid entering the stator member of the twin-turbine Dynaflow torque converter. The fluid, after leaving the second turbine, changes direction upon entry into the stator as shown by arrows A, B, C, and D. The linear velocity of the fluid in relation to the stator blades is shown at F. When the fluid impinges upon the back side of the stator blades, as at D, the stator free wheels along with the fluid so that fluid flow obstruction does not occur.



vectors represented by the letter **S** and its subscripts denote circumferential speed of the pump blades which drive the fluid and the vectors represented by the letter **F** and its subscripts denote the linear velocity of the fluid in relation to the blade.

The absolute velocity of a fluid particle during torque converter operation is the vector sum of the velocity of the converter member it is leaving—which is a tangential vector—plus the vortex velocity of the fluid in relation to the blade it is leaving—which has a vector direction parallel to the exit end of the blade. If the member is stationary, the absolute velocity is the same as the vortex velocity.

Fig. 13 shows the converter pump vector analysis. With a low pump speed S_1 and a high vortex fluid flow F_1, the vector sum is **OA**. With a high pump speed S_3 and a low vortex fluid flow F_3, the vector sum is **OC**. Because the converter pump operates like a simple centrifugal pump, the absolute velocity of the fluid is the vector sum of the circumferential speed of the pump blade which drives the fluid plus the linear velocity of the fluid in relation to the blade. As the pump speed increases and the fluid flow decreases, the vector sum changes in direction and magnitude as shown by vectors **A**, **B**, **C**, and **D**.

Because of its mass and velocity, the fluid contains energy obtained from the car engine. When the direction of the fluid is changed, a force is imparted to the member which causes the change in direction.

Fig. 14 shows a vector analysis of the fluid as it leaves the blades of the first turbine. The vector analysis shows the amount of directional change of the fluid flow between the pump exit and the first turbine exit and, consequently, indicates the force imparted to this member. At stall the turbine speed is zero. The direction of fluid flow, therefore, is tangent to the exit end of the first turbine blade as shown at **F**. This results in the largest change in direction between the entering fluid and the leaving fluid and, consequently, produces the greatest driving force on the first turbine member. The difference in directional change decreases as the first turbine speed increases, as shown by the resultant vectors **A**, **B**, **C**, and **D**. At **D** the high rotational speed of the first turbine causes the fluid to flow between its blades without being changed in direction. At this point the first turbine delivers no drive and the second turbine blades do all of the driving.

Fig. 15 shows a vector analysis of the second turbine. The second turbine, which has curved blades, has a smaller diameter at its exit than at its entrance which enables it to further extract energy from the flowing fluid. The second turbine member functions in the same manner as the turbine member of a simple three-element torque converter. The exit fluid flow for the second turbine member is shown by vector sums **A**, **B**, **C**, and **D**.

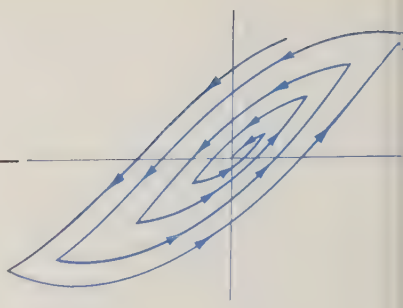
By virtue of the converter planetary gear set, which multiplies the first turbine's torque by a ratio of 1.6 to 1, the speed of the first turbine is 1.6 to 1 faster than the speed of the second turbine while the first turbine is driving. It is this feature which enables the first turbine to reduce its load-carrying ability while the second turbine increases its load-carrying ability. The difference in their speeds is zero at stall and increases as the output shaft speed increases. This causes the first turbine to move ahead of the second turbine so that the latter can take the driving force of the fluid and deliver it directly to the converter output shaft.

Fig. 16 shows a vector analysis of the fluid after it has left the second turbine and enters the stator member. The fluid leaving the second turbine and entering the stator changes in the direction shown by arrows **A**, **B**, **C**, and **D** as the car speed increases and, therefore, imposes a diminishing torque reaction on the stator blades. When the fluid impinges on the back side of the stator blades, as at **D**, the stator free wheels along with the fluid so that it will not obstruct the fluid flow.

Summary

The development of the Buick twin-turbine Dynaflow torque converter has stemmed from utilizing the well-established engineering principles of the basic three-element torque converter. By perfecting this design and incorporating some operating characteristics of the fluid coupling and the twin-turbine and planetary arrangement, an efficient and unique hydraulic drive unit has resulted which, when working in conjunction with a planetary gear set and hydraulic controls, satisfies the requirements imposed upon automotive automatic transmissions.

Resonant and Transient Theory Applied to Control Power in Demagnetizing



In the past, bearings were demagnetized by passing them through a magnetic field caused by an alternating current which was left on constantly. One newer type of demagnetizer studied at New Departure Division utilizes the transient discharge of a capacitor into an inductance. Another type has been developed in which the principle of controlled resonance is applied to make the demagnetizer input a function of the work load.

Frequently, in the manufacture of ferrous parts magnetism is induced somewhere in the production process. This may be done by the use of magnetic chucks, magnetic staking dies, magnetization for crack testing, and by induction heating. In addition, magnetism is sometimes caused by magnetized work benches and by stray fields of motors and generators.

Precision ball bearings are particularly susceptible to induced magnetism because of the complex manufacturing operations involved. The balls themselves are made of high-carbon chromium-steel wire. The wire is drawn and cut into slugs which are headed into approximate spherical shape. Flash grinding, rough grinding, tempering, finish grinding, lapping, and polishing operations follow. The outer and inner rings begin their manufacture in the form of bars of similar metal which are then forged, or the rings may be made from tubing. A series of operations follows which includes machining, grinding, stamping, sand blasting, and finish grinding. Raw material for separators is in sheet form. The manufacturing operations include forming, piercing, tumbling, and staking. In the assembly procedure, the balls, rings, and separators are brought together and the end product is a precision ball bearing having magnetism which, if allowed to remain, would adversely affect the bearing. Among the consequences of magnetism are:

- Reduced life
- High torque
- Noisy operation.

Relative motion of the magnetic poles in a magnetized bearing increases bearing torque; so does the presence of magnetic particles attracted to the raceways. These particles reduce the bearing life as well as cause the bearing to be noisy in operation. Although magnetism is n the only source of these problems, co siderable improvement in bearing quali has been obtained by using a goo demagnetization process after the bea ing has been assembled.

Demagnetization may be accomplishe in one of several ways, any of whi

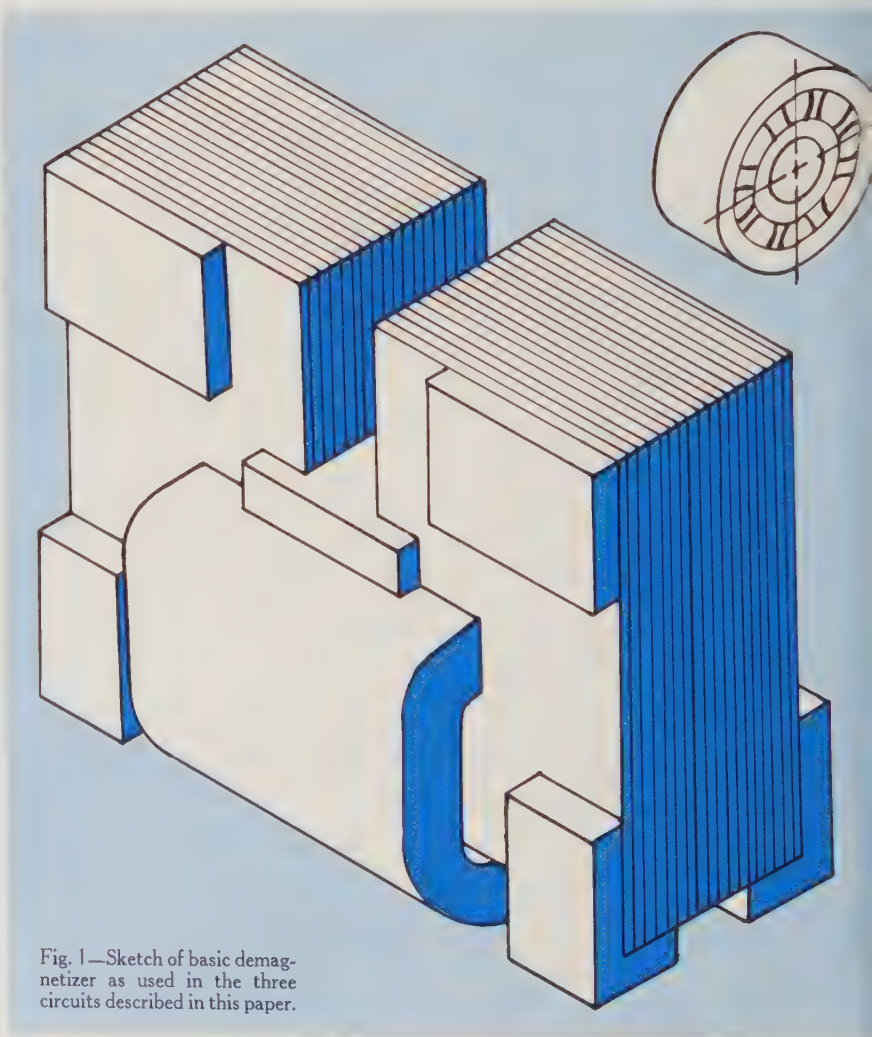
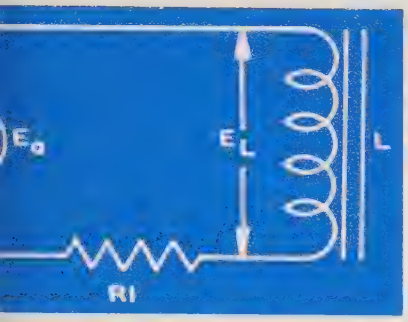


Fig. 1—Sketch of basic demagnetizer as used in the three circuits described in this paper.

By JOE M. RIEDEL
New
Departure
Division

Reducing the input without a loss in effectiveness of the magnetic field



g. 2—Schematic diagram of the conventional magnetizer. L is the inductance of the demagtizer. RI is the resistance due to core losses and pper losses. E_L is less than E_a. Power is obined from a 60-cycle utility line.

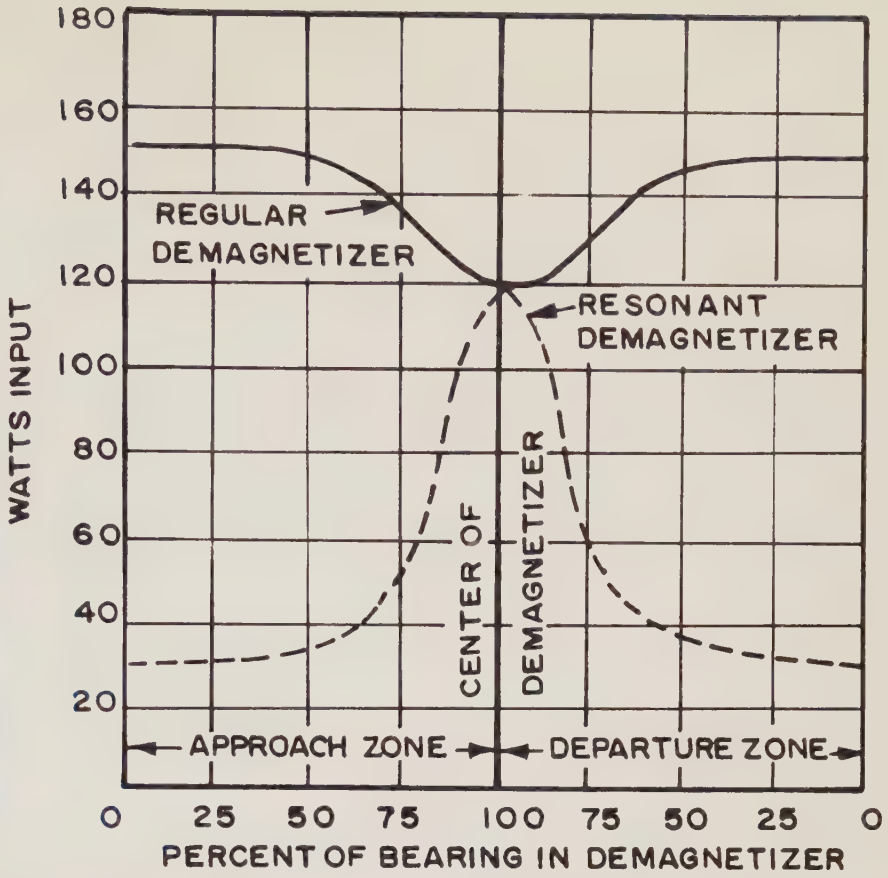


Fig. 3—Curves showing variation of input power to demagnetizer as a bearing passes through the air gap. In stand-by service the resonant demagnetizer consumes 32 w, whereas, the regular demagnetizer consumes 150 w. The flux density in the bearings are the same for both types of demagnetizer at 120-w input.

ust do the following:

- The specimen to be demagnetized must have an alternating flux pass through it.
- The specimen must be subjected to a magnetomotive force that produces a flux density greater than the residual flux density in the specimen.
- The flux density should decrease with each successive alternation until it reaches zero.

The first requirement—generation of alternating flux—can be met by plying alternating current to a degnetizer coil, or by periodic reversals a direct current through the coil and ducing the current by means of a riable resistance. The direct-current thod is not readily adaptable to a pid production process.

On hardened steel parts such as those a bearing, high residual magnetism mands—in accordance with the second quirement—the use of an iron-core magnetizer with an air gap no longer than is necessary to permit free passage of the piece being demagnetized. A sketch of such a demagnetizer is shown in Fig. 1. It is so designed that the ampere turns of the coil are sufficient to cause saturation of the core while the piece is in the air gap.

The third requirement—for slowly decreasing the flux density—may be met by one of several means:

(a) By keeping the input voltage constant and moving the piece through the air gap

(b) By reducing the input voltage to zero while the piece is in the air gap

(c) By a combination of (a) and (b), above.

The conventional type of demagnetizer uses the first of the three methods—input voltage held constant and the specimen pushed through the air gap. This type is connected as shown in Fig. 2. The power input to this type is high and it has the additional undesirable characteristic of decreased power consumption while the specimen is in the air gap, just when maximum power is needed. A plot of this variation in input is shown by the upper curve of Fig. 3. In this particular case, with the demagnetizer input voltage set sufficiently high for complete demagnetization of a production ball bearing, the power input is 120 w, whereas, without the specimen in place the power increases to 150 w.

Under these conditions, with the power being applied continuously, the demagnetizer attains a high temperature after a few hours of operation. The hot demagnetizer then requires even more power to maintain the required flux density due to an increase in the demagnetizer-coil resistance.

There are two principal disadvantages to the conventional utility power-fed demagnetizer:

- Excessive stand-by energy is consumed.
- 60-cycle flux penetration is not sufficient to demagnetize large pieces.

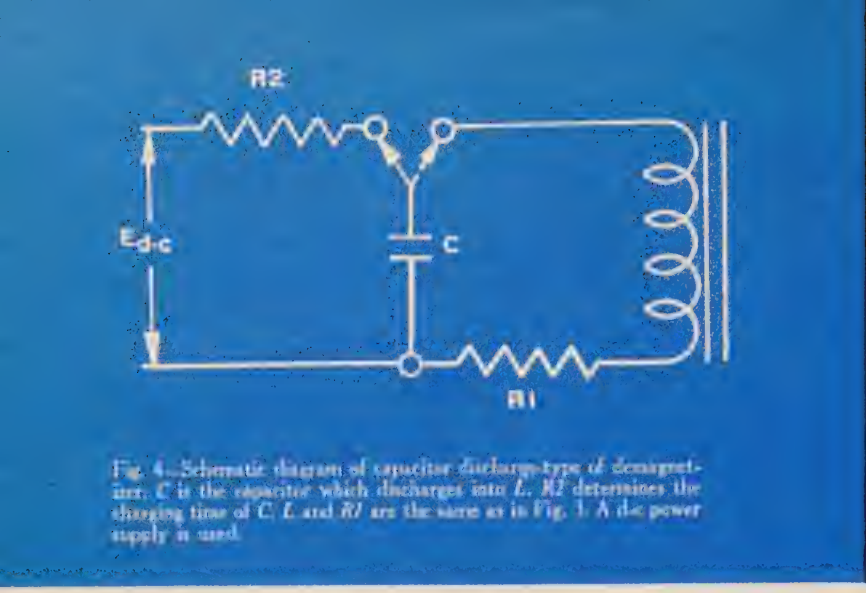


Fig. 4—Schematic diagram of capacitor discharge-type demagnetizer. *C* is the capacitor which discharges into *L*. *R1* determines the charging time of *C*. *L* and *R1* are the same as in Fig. 1. A d-c power supply is used.

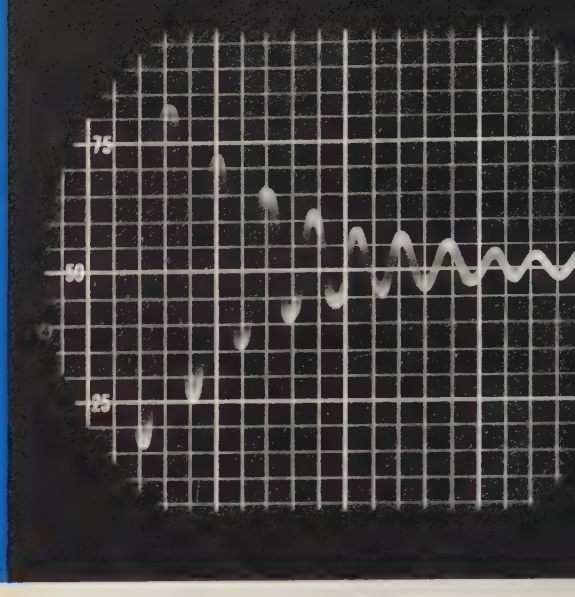


Fig. 5—Oscillogram of current waveform capacitor discharge demagnetizer. The freque of oscillation is 25 cps.

Capacitor Discharge Demagnetizer

The disadvantages of the conventional type have been overcome by the use of a capacitor discharge circuit (Fig. 4). The demagnetizer L is of the same type as the conventional unit (Fig. 1). $R1$ is the effective resistance of the copper and core losses of the demagnetizer L. When the switch is in its normally closed position, the power supply charges capacitor C through $R2$ to the d-c power source value $E_{d\text{-}c}$. The RC time constant, or the time of charging, can be selected according to the needs of the application.

After the capacitor C is charged to voltage $E_{d\text{-}c}$, and with the piece in the air gap, the switch is actuated. This removes C from the charging source and places it across L and $R1$ where it is held until the energy stored in C is completely dissipated, at which time the demagnetization is completed.

If $1/LC$ is greater than $R1^2/4L^2$, the $LCR1$ combination gives a damped oscillation (Fig. 5). The equation for current i through the demagnetizer is

$$i = E_{d\text{-}c}/\omega L\, e^{-\frac{R1}{2L}} \sin\omega t$$

where

ω = $2\pi f = 1/\sqrt{LC}$ (approximately)

t = time (sec)

f = frequency of oscillation (cps)

C = capacitance (farads)

$R1$ = total resistance of the demagnetizer coil, resistance in leads, core losses (ohms).

The term $e^{-\frac{R1}{2L}}$ determines the rate of decay. To assure a large number of oscillations, $R1$ is kept as small as possible. In other words, a high Q demagnetizer is used.

The important advantage to be recognized is that, since the power is applied only during the time of demagnetization, the capacitor discharge demagnetizer does not become overheated.

The capacitor discharge demagnetizer can be designed to oscillate at practically any frequency; consequently, the penetration can be controlled. The frequency of the damped oscillation shown in Fig. 5 is 25 cps.

The direct-current supply for this type of demagnetizer is simple. For instance, a 300-v, 100-ma d-c supply using a voltage-doubler circuit has been found to meet the requirements of many applications.

Resonant Demagnetizer

New Departure Division has developed a system of demagnetization which utilizes the principle of resonance (Fig. 6). The conventional demagnetizer was again used as a starting point. In the new device a capacitor was placed in series with the demagnetizer. The value of capacitor was chosen to cause the circuit to be resonant at the frequency of the applied voltage (60 cps) with a specimen in the air gap. This development was aimed at a particular ball bearing in mass production; hence, the magnetic characteristics of the specimens, as they would affect resonance, were known to be essentially uniform.

Actually, the inductance of the resonant demagnetizer changes as the specimen is moved in and out of the air gap. When the specimen is in the air gap and

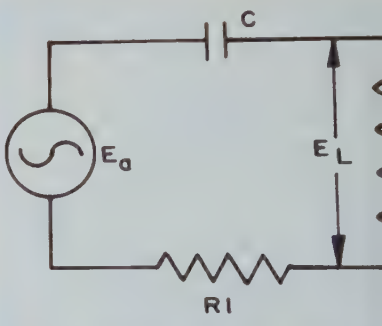
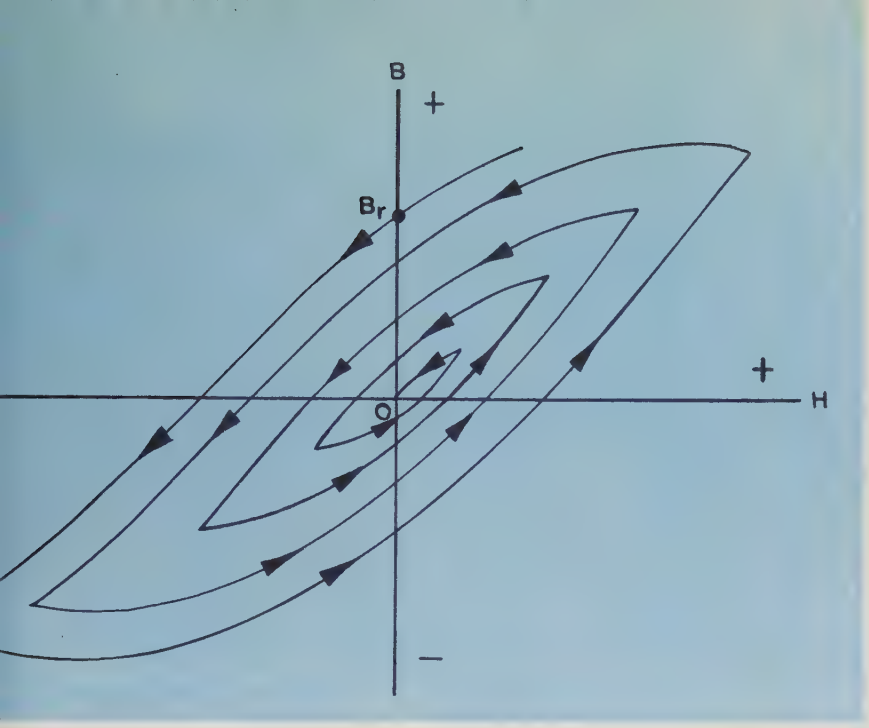


Fig. 6—Schematic diagram of resonant de *LCR1* is a series-resonant circuit. Power from the 60-cycle utility line. At resona several times greater than E_a.

the circuit is at resonance, the dema netizer presents a resistive load to power source. As the bearing is remov from the air gap the circuit becor reactive and the power consumpti decreases (lower curve of Fig. 3). Th the power input to the demagnetizer a function of the location of the bear with respect to the air gap.

The ratio of power consumed wh demagnetizing to power consumed stand-by service may run as high as to 1, depending on the configuration the air gap, the degree of saturat reached, and the Q of the circuit. Fig shows the actual power consumption a practical case. Here, the input increa from 32 w on stand-by service to 12(on demagnetization. Note that the in of the resonant demagnetizer does exceed the input to the conventio



g. 7—A plot of the magnetic state of the specimen as the alternating magnetomotive force H is reduced zero. B_r is the residual magnetism of the specimen. The current shown by the waveform of Fig. 5 ould give 12 loops on the above graph.

emagnetizer, even when the resonant emagnetizer is drawing its maximum ower.

In a series resonant circuit the voltages ross the capacitor and the inductance e several times the voltage E_a applied the series circuit. The demagnetizer as designed to operate at 600 v or less. igher values were found to require tra insulation of the demagnetizer and e use of capacitors rated at impracally high voltages.

When the Q of the demagnetizer with e specimen in the air gap is known, it possible to determine E_a, the voltage plied to the resonant network, from e following relationships:

$E_L = IX_L$

here

E_L = voltage across the inductance of demagnetizer coil (volts)

I = current through the demagnetizer (amperes)

X_L = reactance of the demagnetizer (ohms).

it, at resonance

$$I = \frac{E_a}{R1}$$

$$E_L = E_a \frac{X_L}{R1},$$

ce

$$Q = \frac{X_L}{R1}$$

en

$$E_a = \frac{E_L}{Q}.$$

The magnetic path of a specimen being demagnetized by an alternating current whose value is being decreased with each reversal is shown in Fig. 7. The same type of curve can be obtained by moving the specimen away from a magnetic field of constant intensity.

Summary

Two types of demagnetizer circuits have been used to improve the demagnetizing efficiency over conventional devices for demagnetizing identical parts moving on an assembly line. The capacitor-discharge method has been found to eliminate overheating and to provide greater demagnetization penetration on large pieces when operated at low frequencies. The series-resonant-type does not overheat but is limited to operation from available power frequencies.

Bibliography

Other related literature in this field includes the following:

Lewis, D. M., *Magnetic and Electrical Methods of Non-Destructive Testing* (London: George Allen and Unwin, Ltd., 1951), pp. 78-91.

Mueller, G. V., *Introduction to Electrical Engineering* (New York: McGraw-Hill Book Company, Inc., 1948; 2nd Edition), pp. 285-86.

GM Gas-Turbine Papers Made Available in Brochure Form

Three papers presented by General Motors engineers at the 1954 Summer Meeting of the Society of Automotive Engineers covering work done in General Motors on body, chassis, and power plant development of gas-turbine vehicles have been brought together in a brochure. This brochure carries the story of the development of the gas-turbine-powered Firebird experimental automobile from the general layout to the finished vehicle. Also included is preliminary information on the Turbocruiser, the world's first gas-turbine-powered bus.

The brochure contains these three papers:

- *An Aerodynamic Design in Plastics*, by R. F. McLean, supervisor of special projects in the General Motors Styling Section
- *A Cradle for New Power*, by Robert Schilling, head of the Engineering Mechanics Department of the General Motors Research Laboratories
- *Pinwheels or Pistons*, by W. A. Turunen, head of the Gas Turbines Department of the General Motors Research Laboratories

along with

- *Introduction to Gas Turbine Automotive Vehicles*, by R. A. Richardson, head of the Administrative Engineering Department of the General Motors Research Laboratories.

The brochure is available gratis to engineering educators and engineering students. Requests may be directed to:

Administrative Engineering Department
Research Laboratories Division
General Motors Corporation
P. O. Box 188, North End Station
Detroit 2, Michigan

The Dilution Method for Industrial Waste Disposal

By HUBERT S. KLINE and JOSEPH F. FLETCHER
Frigidaire Division

Regulated discharge of waste solutions solves stream pollution problem

Disposal of chemical wastes into storm sewers presents a serious but solvable problem for industry. At Frigidaire Division, Dayton, Ohio, data collected by reviewing sewer and plant layout drawings, by studying chemical inventories and manufacturing processes, and by making sewer analyses daily for many months, pointed out a reasonable solution to the waste disposal problems of an existing manufacturing plant. Application of engineering experience thus gained suggested the approach to a program for a new appliance manufacturing plant to be built in the same rural area. Consultation with engineers of the Ohio Department of Health resulted in obtaining permission to install systems for regulating industrial waste discharges into the Great Miami River. The success of the program was proven during the drouth period of 1953-54.

An adequate supply of usable water is the base upon which the future of American industry will depend. This statement gains importance when it is learned that the tonnage of water used by General Motors, for example, is about seven times that of all other raw materials purchased. Hydrological records of underground water supplies, used by many cities and industries in the Midwest, show a steady decline in the water tables as a result of drouth conditions starting in late 1952 and becoming more severe in 1953. Meteorologists reported serious rainfall deficiencies for 1953 causing many streams and small lakes to shrink or to dry up completely. Water supplies for many cities were reduced to a trickle or were totally exhausted. Farmers also experienced water shortages which were reflected in loss of income derived from crop failures and lowered livestock production. Authorities have observed these cycles of low rainfall occurring every 10 years. However, increased population and increased usage of water by individuals as well as by industry poses a serious problem for the near future.

One answer to increased demands for water, and the apparent shortage of it, lies in better watershed management. The late Professor C. E. Sherman of The Ohio State University is quoted as saying, "God carries the water to the top of the hills; it is up to us to make it walk slowly and usefully back to the sea." This is a wonderful way of saying that nature supplies us with water continuously through the years by the hydrological cycle. Salt water from the sea is evaporated by the sun to form clouds which are blown over land by winds and distribute clean rain water or snow upon the land.

About 65 per cent of the normal precipitation falling over Ohio is again returned to the clouds by evaporation or transpiration from crops, trees, grass, and other foliage. Man uses another 13 per cent of the rainfall for his domestic and occupational needs, allowing the remaining 22 per cent to run back to the sea. Monthly rainfall distribution varies, being heavier during the earlier part of the year and sometimes very light during hot weather periods.

This clearly shows that there is immediate need for united effort toward the building of storage reservoirs and regulating devices to control rainfall run-off for the beneficial needs of mankind.

Pollution abatement has received considerable public attention in recent years. This was especially true of the period following World War II. During the war, emphasis was placed, by necessity, on the production of war goods while pollution of public waters passed unheeded. However, as gasoline became available, the public sought recreation in the out-of-doors only to find streams grossly polluted by sewage and industrial wastes. Legislation passed by public demand has stimulated progress toward keeping pollution from public water courses.

Domestic sewage can be treated biologically or chemically by several well-known types of treatment. On the other hand, the treatment of industrial wastes may be difficult, depending upon the nature of the product manufactured and the wide variety of chemical solutio which must be discarded during pla operation. The management of most i dustries is keenly aware of its public rel tions problems and therefore has directe its engineering staffs to survey the waste-treatment requirements.

Pollution Abatement in General Motor

General Motors recognized the strea pollution-abatement problem many yea ago. The first approach made on a organization-wide basis was the esta lishment of the General Motors Ind trial Waste Control Committee wh met for the first time in October 1945 discuss overall problems relative to wa treatment. At the first meeting the Co mittee agreed that efforts should be ma by the managements of all GM Divisio to decrease the discharge of waste chem cals into public waters by promoti more complete utilization of materia

The Committee further encourag each Division to survey and study its ow individual problems of industrial was disposal and to take action to rend these wastes harmless to sewers, strea life, water, and sewage treatment pro esses. Plans were made to collect a disseminate information for the educ tion of those persons in each of the Di sions responsible for controlling indu trial waste. The Committee's progra on industrial waste control was readi adopted by General Motors as policy.

The Management of Frigidaire w quick to take action in line with t program of the General Motors Indu trial Waste Control Committee. Late 1945 a complete survey was made in a plants to define the industrial was problem. Industrial Waste Plannir Committees were organized in each the four existing Frigidaire plants. Co

ttee members included the director of nitary Engineering as chairman, the ant superintendent, his assistants in arge of Production and Mechanics, e heads of the Chemical Control Labotory, Process, Maintenance Departent, and Instrument Laboratory.

The primary work of the survey was rried out by members of the Chemical ntrol Laboratory and the sanitary gineer. Investigations were made of e sewer systems, plant layouts, inventry of chemicals being used, dumping nedules, and stream and sewer flows.

Five Frigidaire Plants

To aid in the understanding of the pproach taken to the problem, it is ppropriate to examine briefly the arngement of plants and existing disposal stems in use at Frigidaire.

The Division has five large plants in e Dayton, Ohio, area. Plant 1 is cated about one mile east of the center Dayton on the Mad River. All plating d processing chemical wastes are presitly discharged into the sanitary sewer a system of regulated discharge.

In Moraine City, approximately six iles south of Dayton, there are four ants (Fig. 1). Plants 2 and 5 are rviced by a common sewer 84 in. in ameter which is jointly owned by oraine City and Frigidaire. The sewer scharges into an open ditch flowing to the Great Miami River, west of the ant property. Plant 4 was built during orld War II and is located just west Plant 2. Storm sewers from the original ant 4 building carry a small amount of dustrial waste and flow south to interpt the main sewer. Plant 3 was conructed northeast of Plant 2 in 1950-51 d began operation as an assembly ant in 1952. A new 66-in. storm wer was laid to carry storm water to open ditch and thence to the Great iami River at a point along the shore proximately one-half mile north of e old plant sewer. Storm water from new addition to Plant 4 is also disarged into the Plant 3 sewer. All of e Moraine City plants have separate nitary sewers connecting into the Montmery County sanitary-sewer system.

udy of Chemical Processes and Solutions

To solve the problems of modifying a ge existing plant (Plant 2) for the option of the dilution technique of posal, the first step was concerned with a study of the chemical processes and solutions used in the plant.

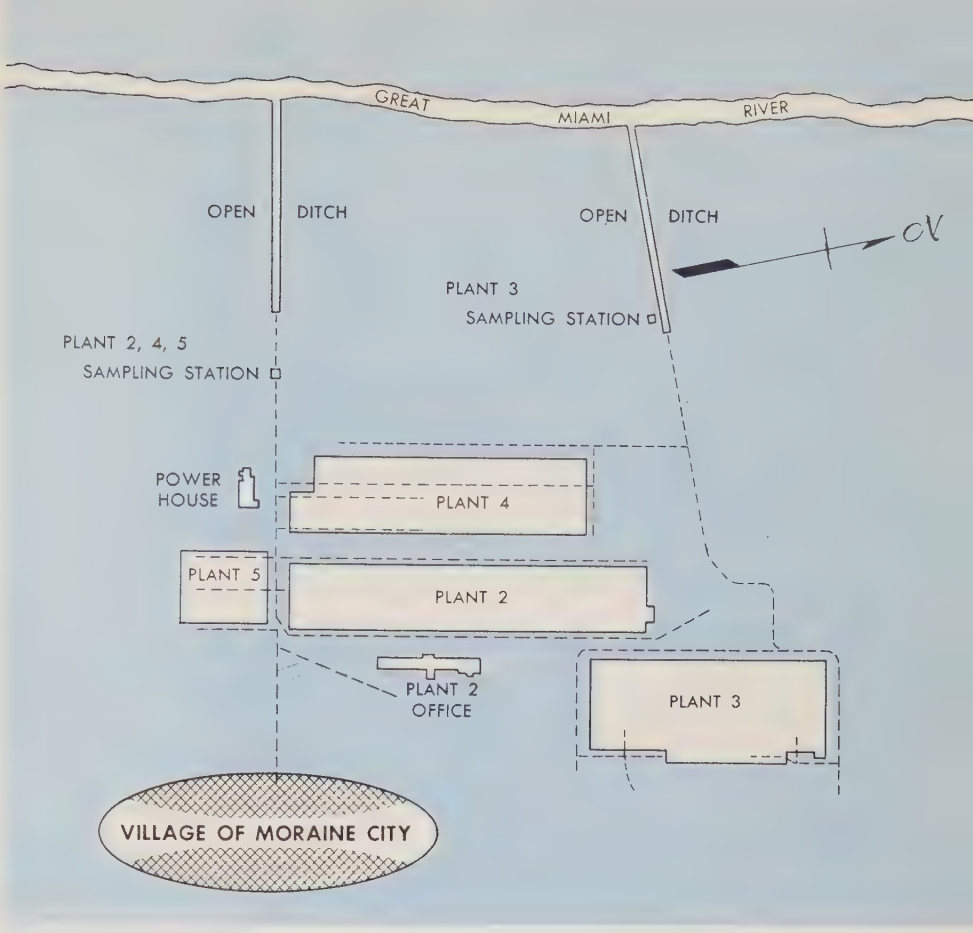


Fig. 1—Plant and storm-sewer layouts for Frigidaire Division Plants 2, 3, 4, and 5 located in Moraine City, Ohio, south of Dayton. The dilution method was first applied to the industrial wastes for Plant 2 and then was used successfully for Plant 3, which started manufacturing operations in 1952. The two sewer sampling stations are focal points for the collection of data establishing the character of the sewer flows enroute to the Great Miami River.

A preliminary survey of the production layout of Plant 2 indicated that the principal chemical processes which created industrial waste were not located in any small area of the plant. An inventory of chemical solutions in use showed that the principal sources of wastes, rated on a volume basis, that required monthly disposal were dilute sulphuric acid—used in anodizing and pickling operations—dilute alkali cleaning agents, cyanide solutions, and caustic soda—used in stripping paint from steel cabinets. The more concentrated metal cyanides, such as zinc, cadmium, and copper, were not discarded but were reprocessed and reclaimed.

Other sources of industrial wastes resulted from aluminum etching operations which used nitric acid, bright-dipping operations using nitric and sulphuric acids, tin-plating systems, chromium plating, and other miscellaneous acids and alkalis required for plating.

For the year 1953, the following amounts of chemicals were discarded from Plant 2:

sulphuric acid	142,000 lb
sodium hydroxide	124,000 lb
orthosilicate	86,600 lb
nitric acid	29,900 lb
hydrochloric acid	8,150 lb
sodium cyanide	6,700 lb.

The above weights of chemicals were distributed into an effluent flow of approximately ten million gallons of water per day or 30.4 billion lb of water per year. This volume represented the average sewer flow, including plant waste and storm water drainage.

It should be mentioned here that adequate dilution takes place before the wastes enter the stream. The acids and alkalis, when discharged together, tend to neutralize each other in the flow. Sodium cyanide discarded into a volume of water as mentioned above will be diluted to about 0.1 part per million as CN. Further dilution is afforded the wastes when they reach the stream.

Waste Disposal Scheduling

A definite disposal schedule for all of the major chemical processes in Plant 2 had not been established. It soon became apparent that a system of disposal controls would be needed so that the supervision of the several different manufacturing departments would not dispose of their waste solutions whenever they desired and at whatever rate they thought necessary. Preliminary examination of the chemical inventory and water usage records also indicated the possibility of neutralizing and diluting waste solutions in the rinse and cooling waters flowing from the plant.

The Chemical Control Laboratory was designated as the control center from which all waste disposal orders would originate; responsibility for carrying out the orders was given to the Maintenance Department. The disposal orders described the process tank to be dumped, the volume and analysis of the solution to be dumped, and also the date, time of day, and rate at which the discharge should be made.

The value of having a disposal schedule became apparent soon after the Chemical Control Laboratory began issuing disposal orders. Prior to establishing a disposal schedule, many solutions had been disposed of prematurely. By prolonging the interval between waste-solution disposal, a salvage of materials was effected.

Sewer Sampling Program

Two storm sewers, running parallel to Plant 2 (Fig. 1), are located beneath shipping platforms. The east storm sewer, of rectangular cross section, receives the largest portion of industrial waste solutions and about one-half of the roof drainage. The west sewer, of circular cross section, increases in diameter from 24 in. to 42 in., at which point it joins the main sewer. The main sewer increases in diameter from 36 in., at its starting point, to 84 in., and then enters an open ditch. The open ditch receives the storm-sewer flow and carries it 1,400 ft to the Great Miami River.

The Industrial Waste Planning Committee decided that it would be advisable to have information regarding flow rates, pH readings, and chemical analyses of water flowing through the sewer in order to determine the amount and character of the combined sewer flows enroute to the Great Miami River. This decision resulted in the building of a sewer sampling station near the end of the storm sewer carrying waste waters from Plants 2, 4, 5, and the power house.

The sewer sampling station was built over a manhole on the 84-in. diameter storm sewer positioned 15 ft below ground at the point of the station's construction. The location of the sewer sampling station with respect to Plant 2 is shown in Fig. 1.

It was contemplated by the Industrial Waste Planning Committee that data obtained, resulting from the establishment of the sewer sampling station, would serve to define the scope of the waste problem, point out the major contaminants requiring attention, indicate the time of day when the most serious pollution occurred, and provide flow figures which could be used to properly determine waste disposal rates. The data obtained would also provide information needed for filling out 24-hr record forms for filing at the plant and with the Ohio Department of Health engineers.

These reports, compiled for each month, contain storm-sewer chemical data based on 24-hr composite samples, and they record daily pH readings and rates of sewer flow and river flow.

The sewer sampling program required the purchase of various items of equipment, most of which are still in use. The pH recording apparatus used is a glass-electrode, flow-channel type instrument provided with strip charts for continuous reading and having a variable range from pH 2 to pH 12. A small pump lifts a portion of the flowing waste from the sewer and provides a continuous flow through the electrode chamber. Infrared heat bulbs, mounted at several locations on the ceiling of the sampling station, keep moisture from causing interference with the electrode terminals in damp or cold weather and likewise prevent liquids from freezing.

Flow records are kept on circular 24-hr charts. The measurement of flow is effected by transferring pressure impulses equivalent to the head of water passing over a 10-ft wide, sharp-crested weir constructed across the open ditch several hundred yards below the sewer sampling station. Transmission of the pressure impulses is made through a marine cable which is laid in the open ditch and the sewer between the weir and the sampling station. The pressure diaphragm equipment used for measuring flow is mounted in the open ditch above the weir and requires monthly servicing to prevent mud from affecting the recording instruments.

At first, a sampling pump was installed in the sewer sampling station which collected small amounts of flowing waste continuously in proportion to sewer flow. The sample was collected in a large crock which held the entire 24-hr composite. The mixed waste sample did not satisfy the established survey requirements for accuracy. Plans were made to collect *grab samples* at 10-min intervals and composite them in 24 separate 1-hr sample bottles each day. Laboratory examination of the hourly samples would show more exactly the character of the flowing sewer wastes. A small portion of the 24 samples could be taken and composited into a single sample for the daily average sample.

An automatic sampling apparatus was designed by Frigidaire Division engineers especially for the sewer sampling program. The apparatus is essentially a compressed air, lift device which takes a 10-cc sample of waste and distributes it into a 2-qt sample jar by means of a rotating distribution table. After six samples are thus collected, the table rotates to the next position and another hourly sample is collected. Analyses are made according to procedures approved by the regulatory agencies of the State of Ohio.

A few months after the sewer sampling program was established, the information gathered and the results obtained tended to show that a satisfactory solution to the waste disposal problems of Plant 2 was possible. The waste solution disposal orders issued by the Chemical Control Laboratory were effective in stopping the indiscriminate wasting of chemicals as well as arresting the pollution of the Great Miami River by the method of instantaneous disposal of concentrated batches or *slugs* of chemicals. The regulation of waste discharge over long periods of time, such as 12 hr to 24 hr, allowed the effluent to remain between the pH range from 5 to 10. The concentration of more toxic chemicals such as cyanide compounds, was maintained at less than 0.15 parts per million in the river, which is the maximum stream standard established by the Ohio Department of Health.

This temporary waste disposal program, although effective, was not without problems of its own. The Maintenance Department found it necessary

CHEMICAL WASTE SOLUTIONS

HOLDING TANK	CAPACITY (GALLONS)	SOLUTION CONCENTRATION	MAXIMUM DISCHARGE RATE	DISCHARGE TO
1	25,000	Sodium Cyanide 0.28 to 0.55 oz/gal	2.87 gpm	Sewer
2	26,000	Sulphuric Acid—5% Sodium Orthosilicate 6 to 8 oz/gal	6.67 gpm	Sewer
3	4,000	Sodium Hydroxide 12 to 20 oz/gal	2.25 gpm	Sewer
4	4,500	Sodium Hydroxide 12 to 20 oz/gal	2.25 gpm	Sewer
5	18,000	Sulphuric Acid—10% Nitric Acid—4%	2.11 gpm	Sewer
6	18,000	Sulphuric Acid—10% Nitric Acid—4%	2.11 gpm	Sewer
7	8,000	Sodium Cyanide 0.28 to 0.55 oz/gal	100 gpm (approx.)	Tank No. 1
8	4,000	Sodium Cyanide 0.28 to 0.55 oz/gal	0.5 gpm	Sewer
9	9,200	Sulphuric Acid—10% Nitric Acid—50% Alkali Etch—4 oz/gal Alkali Etch—2.5 oz/gal	1.25 gpm	Sewer
10	2,600	Nitric Acid—50% Alkali Etch—1 oz/gal Sodium Silicate—2 oz/gal Alkali Cleaner—4 oz/gal	1.25 gpm	Sewer

Table I—Ten holding tanks were necessary to handle the waste solutions for Plant 2. The above table lists the chemical concentration handled by each holding tank. The dilution method for disposal of the solutions centered about regulating their discharge from the holding tanks.

o have plumbers on hand over the week-nd to control the discharge of waste olutions. There also were instances when nsufficient time was provided to clean, epair, and refill the process tanks for Monday morning production schedules. No provisions could be made in such a emporary program to take care of acci-ental or emergency spillage of waste olutions from the process tanks. For hese reasons, the Industrial Waste Plan-ing Committee continued its engineer-ng studies in an effort to develop a more ermanent type of waste disposal system.

Establishment of a Permanent Waste Disposal Program

After the temporary waste disposal rogram for Plant 2 had been in exist-nce for approximately eighteen months, he Industrial Waste Planning Com-ittee made plans for a permanent waste isposal program. Four general plans for andling industrial wastes were con-dered. These were:

- Lagooning
- Complete chemical treatment
- Partial chemical treatment in the sewer
- Regulated discharge from holding tanks (controlled dilution method).

agooning

The disposal of waste solutions by the ethod of lagooning proved to be im-ractical for several reasons. The plant property and adjoining neighborhood did not contain an area of sufficient size on which a lagoon could be built for satisfactory dilution of the total Plant 2 effluent, which measured approximately 7,000 gpm. The topography of the land and the location of the storm sewer 15 ft below ground level were two factors not suited to lagooning. Also, there was the danger of the river washing out the banks of the lagoon during flood stage, which would allow the entire volume of settled sludge and lagoon contents to be washed into the river.

Complete Chemical Treatment

The Committee considered thoroughly the building of a chemical treatment plant on plant property approximately a quarter of a mile from the south end of the Plant 2 building. The cost of construction for a chemical treatment plant of sufficient size to treat the entire volume of waste flow was prohibitive and for this reason this plan was discarded. On the other hand, to treat only waste water containing the waste solutions would require an extensive sewer construction program throughout Plant 2, which would involve shutdown of production and other additional expenses.

Partial Chemical Treatment in the Sewer

The partial chemical treatment program proposed the construction of a chemical building built above an opening into the storm sewer. A pH meter would indicate when either acid or alkali chemicals should be added to neutralize the flowing sewage and waste. Such a meter, however, would not indicate toxic constituents, such as cyanide or metal salts. It was shown that chemical additions made directly into the sewer would create sludge which would be carried with the sewer flow into the river. This plan also was vetoed.

Regulated Discharge from Holding Tanks

Having reviewed the data obtained from sewer and plant layout surveys, the sewer sampling program, and the temporary control discharge procedures for disposal of wastes, the Committee decided in favor of enlarging on the controlled dilution method of waste disposal. The Ohio Department of Health engineers were called in and gave official approval to the proposed program.

Studies indicated that the major processes of Plant 2 which required attention included three pickle systems, three anodize systems, two paint-stripping tanks, several cyanide solutions in the Plating Department—including two large automatic zinc-plating systems—and an etching process for aluminum. These processes included process tanks of larger size containing various concentrations of chemicals.

To reduce the labor time required for week-end disposal and to provide space for receiving accidental or emergency spillage of solutions, it was deemed advisable to build holding tanks of sufficent size to retain at least twice the volume of the largest waste solution requiring disposal. Curbing was constructed beneath the critical tanks to divert any leakage into the proper holding tank. A total of 10 holding tanks were built to handle the solution concentrations indicated in Table I.

Inasmuch as the cyanide plating solutions are not disposed of but are reclaimed, it was first considered advisable to build sump pits beneath the cyanide plating solution tanks equal in size to the volume that might be accidentally lost. The Committee decided, however, to build double-walled tanks when experience indicated that there would be some difficulty with keeping rinse waters from filling these sumps.

The inner walls of the cyanide plating tanks are covered with plastic coatings which prevent stray electrolytic currents from weakening the steel tank walls dur-

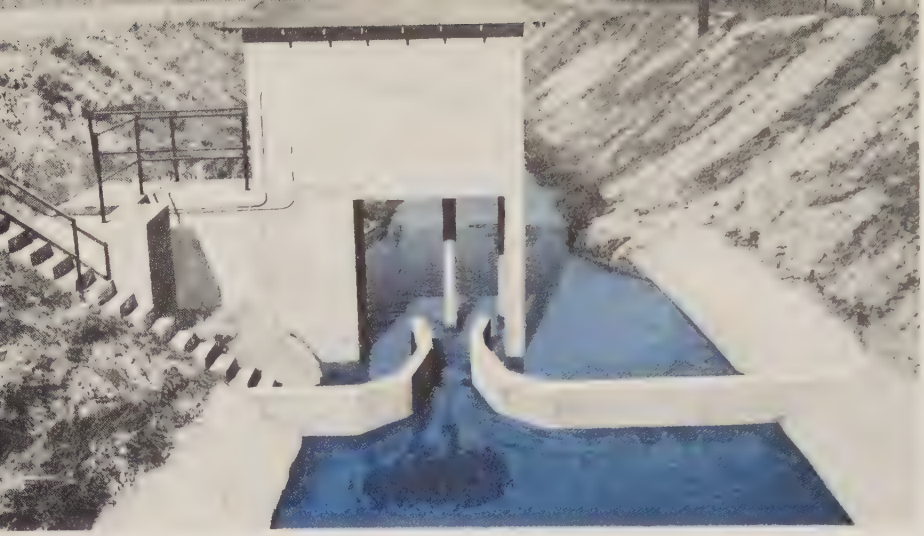


Fig. 2—View of the Plant 3 sewer sampling station and the Parshall flume used for measuring sewer flow. In the foreground is the stilling basin for flow measurements. Directly below the station is one of the two 8-in. diameter pipes through which samples are collected and pH readings determined. (Left) Dry well in which are located the water-level measuring column and flow transmitter.

ing many hours of use. Such tank-within-a-tank construction has the advantage of being mobile in case the cyanide plating process is moved to another location in the plant.

Reinforced concrete was used in the construction of all underground holding tanks. Tanks receiving acids and alkalis were lined with acid-resistant brick which was backed by an acid-resistant membrane cemented to the concrete. Either tile or furan resin piping was considered satisfactory and was used to connect tanks and drain basins.

Inlet pipes discharge into a small settling chamber, allowing the settled waste to pass over a baffle wall to the holding-tank space. Mixed wastes are discharged to the nearest storm sewer in small amounts and over long periods of time by air-ejector mechanisms. Arrangements also are made to remove sludge from the acid-alkali holding tanks at least once a year.

Experience Applied to New Plant Construction

In 1950 Frigidaire prepared to build a new manufacturing plant (Plant 3) adjacent to Plant 2 at Moraine City. The experience gained in developing a workable solution for the waste disposal problems of Plant 2 influenced the actions of the Industrial Waste Planning Committee assigned to work out a similar disposal program for the new plant.

The plans for the disposal of industrial waste from Plant 3 were made and approved by the Ohio Department of Health engineers. In brief, the plan embodied the regulated discharge procedure previously proved satisfactory in Plant 2. Instead of constructing 10 holding tanks in many locations, however, it was possible to build separate collection sewers within the plant which would carry acid-alkali and cyanide wastes to two large holding tanks built underground and northwest of the Plant 3 building.

Several advantages were possible with this plan over the one that was necessary for Plant 2. If new chemical processes were added within the building, waste lines could be run short distances to connect into the proper collection sewer. Should chemical waste treatment be necessary in future years, concentrated chemical wastes could thus be segregated from rinse waters and treatment rendered more economically. Construction costs were likewise reduced by building only two holding tanks and laying the sewer lines before the building floors were poured.

The two concrete holding tanks, each having a capacity of 27,000 gal, are constructed underground approximately 75 ft northwest of the Plant 3 building. These tanks were built end-to-end so that one wall is common to both tanks.

The tank which receives acids and alkalis is lined with an acid-resistant membrane cemented to the concrete wall and this membrane is protected by acid brick, located on the floor and up each wall to a distance of almost 2 ft from the top of the tank. Water-injection-type pumps are used for expelling the tank contents into 1-in. diameter pipe lines which transfer the chemical solu tions nearly 450 ft to a junction box o the 66-in. diameter storm sewer. Nearl 3,000 ft of 10-in. and 12-in. diamete vitrified tile pipe is used to collect acids alkalis, and cyanide wastes from withi the building.

The Plating Department is located i the northeast area of Plant 3 and i serviced by an acid-alkali and cyanid collecting sewer. The two large spray type pickle machines are located in th north-central part of the plant and also have separate cyanide and acid-alkal collecting sewers. Rinse waters ar dumped into a separate storm-sewer sys tem connecting each process. The collect ing sewers run north, parallel with th building walls, to the outside of th building where they cross westwardly t the holding tanks.

Two large zinc-cyanide plating con veyor systems are built above concret sump pits which serve to trap the con tents of the cyanide tanks should acci dental loss occur. The pits are connecte to the cyanide holding tank but ar plugged to prevent the plating solutio being lost. These concentrated platin solutions are not dumped but are re claimed for reuse.

Chemical Sampling and Control for the New Plant

As in the waste disposal program s up for Plant 2, the Chemical Contro Laboratory of Plant 3 is responsible fo issuing waste disposal orders to the Main tenance Department for the purpose o preventing the unnecessary disposal o chemical solutions throughout the plan Chemists make daily inspections of al process solutions and also take sample from the two holding tanks to determin the concentration of their contents.

In the last seven months of 1953, th following amounts of chemicals were dis carded from Plant 3:

sulphuric acid	26,300 lb
sodium hydroxide	1,030 lb
orthosilicate	60,400 lb
nitric acid	100 lb
hydrochloric acid	1,900 lb
sodium cyanide	600 lb.

Sewer water for the same seven-mont period averaged 5.2 million gal per da or a total of 15.8 billion lb of water.

Due to the careful control exerted b the Chemical Control Laboratory, th chemicals disposed of were properly dis charged and effectively diluted to satisf

present-day stream standards. The Chemical Control Laboratory also is responsible for making daily analysis records of flowing waste collected by automatic sampling equipment from the 66-in. diameter storm sewer.

A chemical sampling program was planned similar to that in use on the Plant 2 sewer. After a study of the records and the efficiency of the sampling equipment at the Plant 2 sewer sampling station it was decided by the Committee to measure flow through a *Parshall flume* rather than by a rectangular weir. This decision was based on the self-cleaning advantage of the flume and also the higher accuracy in flow measurements obtainable.

The concrete Parshall flume has a 2-ft wide throat and a free fall at its outlet end. The structure comprising the flume is built in the open ditch about 50 ft from the end of the 66-in. diameter storm sewer and creates a stilling basin ahead of the flume. Fig. 2 shows a view of the Plant 3 sewer sampling station and the Parshall flume.

The walls of the flume are 3 ft high, thus permitting heavy storm flows to pass over the structure without restriction. Flow is measured by recording the elevation of flow through the throat of the flume. The measurement is then transmitted laterally through a pipe to a stilling basin built against the wall of the open ditch. A circular 48-hr chart-type flow meter records the flow from the storm sewer.

The pH meter used is installed to measure pH directly in the sewer as the waste water flows over the immersion electrodes. Such equipment does not require a pump for lifting the storm water (as in the case at the Plant 2 sewer sampling station) and, therefore, avoids the need for pump maintenance. The glass electrodes of the pH meter are lowered into an 8-in. diameter pipe which stands in the open ditch about 10 ft below the Parshall flume outlet. Holes in the pipe permit a free exchange of water to pass over the electrodes. Records of pH readings are kept on a strip chart in the sewer sampling station.

The automatic chemical sampler is of the same design that is used in the Plant 2 sampling station and which has been described previously. The only difference that exists between the two chemical samplers is that the one for Plant 3 is built to sample 48 hr rather than 24 hr per cycle. Fig. 3 shows a view of the automatic chemical sampler apparatus installed in the Plant 3 sewer sampling station.

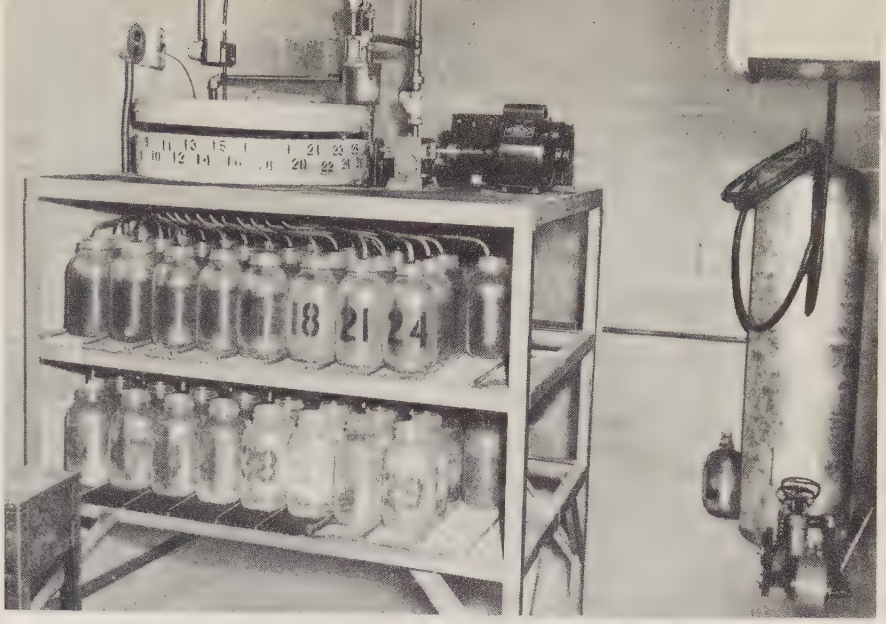


Fig. 3—Automatic sampling apparatus used to analyze samples of waste solutions taken from the storm sewer. The apparatus, designed by Frigidaire Division engineers, is essentially a compressed-air, lift device which takes a 10-oz. sample of waste and distributes it into a 2-qt jar via a rotating distribution table. When six samples have been collected the table rotates to the next position and another hourly sample is collected. At the right of the figure is the small air compressor and pressure tank used for blowing the sample from the sewer up to the sampling apparatus.

Operation Under Drouth Conditions

Even though the flow of the Great Miami River was below normal for several months during 1953, operating results of the Industrial Waste Disposal Program at the Moraine City Frigidaire plants indicate a successful solution to the waste disposal problem. The receiving stream flow for 1953 averaged 1,282 cfs; however, examination of the records for the first six months of the year showed an average flow of 2,240 cfs. During the four dry-weather months at the end of 1953 the flow averaged 247 cfs. Lowest flow was 174 cfs on September 3. Engineers from the Ohio Department of Health have established the critical velocity for the Great Miami River at Dayton at 225 cfs. When the river flow is less than this volume, the stream loses its capacity for self-purification and may become stagnant or septic. The river was in the critical stage a total of 51 days during the last four months of the year. Further examination of river flow records from April 1947 through December 1952 fails to show any date on which the river was at the critical velocity flow of 225 cfs. The lowest previous flow was 280 cfs in September 1947.

Summary

The results that have been achieved in the waste disposal program in Plants 2 and 3 indicate that concentration of industrial wastes can be reduced by the regulated discharge of waste solutions from holding tanks. This has been proved by a program of continuous sewer-sampling and plant-effluent analyses.

Furthermore, the establishment of laboratory control centers for issuance of dumping notices has resulted in a saving of chemicals by prolonging their use or by reclaiming procedures.

In the construction of the regulated discharge system, it has been found that double-walled tanks definitely prevent accidental loss of concentrated cyanide solutions.

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Applying Radiochemistry to the Manufacture of Oil-Filter Elements

A goal of many industrial laboratories today is to find solutions to various design and manufacturing problems through industrial research with the aid of radioisotopes. Such problems often seem relatively easy to scientists; however, operational and administrative stumbling blocks often appear, stemming from the potential or real personnel hazards involved in the use of nucleonic tools. The AC Spark Plug Division has successfully applied radiochemistry to the solution of a problem in the manufacture of filter-paper elements for oil filters used by internal-combustion engines. The custom-made filter paper is impregnated with a thermosetting phenolformaldehyde resin which is ultimately oven-processed. Tests with radioactive materials indicated that the resin could be cured to lower percentage values than before without resulting in contamination of the engine lubricating oil. Substantial savings in curing costs with improvement of quality are the potential results of this study.

One of the first industrial applications of radioisotopes by General Motors was made at the AC Spark Plug Division, Flint, Michigan, in the manufacture of the Aluvac oil filter for internal-combustion engines.

Oil cleanliness has a directly measurable correlation with engine wear, with operating and maintenance costs, and with length of time between engine overhauls. It is, therefore, essential that the oil filter effectively remove all contaminating substances from the engine lubricating oil.

In the AC Aluvac filter, this filtering medium is a bellows construction assembled from carefully selected, custom-made filter papers (Fig. 1). To give resistance against collapse when it becomes loaded with dirt, thus causing a relatively high pressure drop across the bellows, the paper is impregnated with a thermosetting phenolformaldehyde resin which is custom-engineered exclusively for this application. This resin must be such that it does not cause significant blocking of the filter-paper pores and that it enables the paper to be handled easily by the bellows-folding machine. The resin also must impart strength as well as resistance to collapse without causing the paper to become excessively brittle. It also renders the paper resistant to water and to the acids in the lubricating oil which result from blow-by and from oil oxidation.

The filter paper is impregnated with the uncured resin as the first step in the manufacturing process. After the other assembly operations are completed, the elements are cured in ovens according to definite time and temperature specifications. In examining this part of the manufacturing process, it is significant to note that the time required for the established cure is about twice the time necessary to achieve a somewhat lower cure.

Reduced Curing Time Desired

An increasing demand for the Aluvac oil-filter element necessitated several expansions of manufacturing facilities at the AC Spark Plug plant. Since the curing ovens in the filter-element assembly line were physically the largest items and entailed considerable expense for purchase, installation, operation, and maintenance, cost savings in the curing process appeared to offer the greatest benefit in planning additional expansion of facilities. If curing time could be reduced, manufacturing capacity could be increased without the expense of additional ovens. It was not known, however, how low a cure could be made without the danger of resin entering the engine oil during service. Furthermore, if a lower cure could be used without danger of contamination of the lubricating oil, there would result an element of increased resistance toward damage from dropping or other mishandling prior to the beginning of its service in the customer's equipment. A significant, though slight, increase in ruggedness while in service would also result. Therefore, a lower cure could, potentially, raise the quality of the product if no resin contamination of the lubricating oil resulted. The problem, then, was to determine the quantity of resin, if any, that was lost from the filter paper at cures lower than the established value.

One solution that seemed promising involved the use of radioisotopes and nucleonic counting and recording equipment. It was recognized, however, that there are operational and administrative stumbling blocks in the use of nucleonic tools, all of which stem from the potential or real personnel hazards involved in their use.

Since there was no Divisional personnel who had the training and the experience to receive and to use radioisotopes under the regulations set up by the Atomic Energy Commission, the Division made arrangements to send one of its personnel to the University of Michigan at Ann Arbor to receive both theoretical and laboratory radiochemical training. A semester of once-a-week training sessions qualified this employe for the receipt and the use of millicurie amounts of radioactive materials.

Furthermore, it was desirable to avoid constructing and equipping a radiochemical laboratory at AC Spark Plug Division in Flint when similar facilities in General Motors were being planned not too far away at the GM Technical Center, north of Detroit. Arrangements were made, therefore, with the University of Michigan for the use of certain facilities already available in Ann Arbor. Such facilities included a relatively wide selection of nucleonic counting and recording equipment, radiochemical

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AC Spark Plug Division

Radioisotopes proved the safety of lower resin cures for filter elements

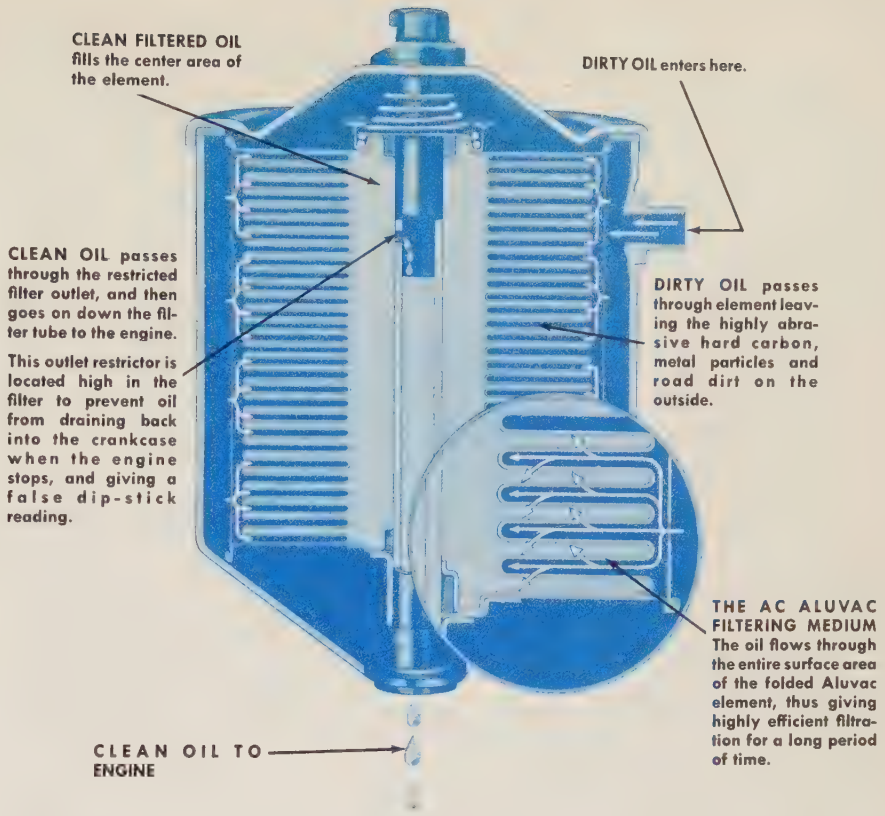
CLEAN FILTERED OIL fills the center area of the element.
DIRTY OIL enters here.
CLEAN OIL passes through the restricted filter outlet, and then goes on down the filter tube to the engine.
This outlet restrictor is located high in the filter to prevent oil from draining back into the crankcase when the engine stops, and giving a false dip-stick reading.
DIRTY OIL passes through element leaving the highly abrasive hard carbon, metal particles and road dirt on the outside.
THE AC ALUVAC FILTERING MEDIUM
The oil flows through the entire surface area of the folded Aluvac element, thus giving highly efficient filtration for a long period of time.
CLEAN OIL TO ENGINE

Fig. 1—The Aluvac oil filter, manufactured by AC Spark Plug Division, is a typical extended-area filter, used generally with internal-combustion engines. The filtering medium is made of custom-engineered filter paper which is treated with a thermosetting resin and formed into a bellows construction to give each convolution ample oil passage. (Lower right) The inset shows an enlarged portion of the bellows construction which provides 10 times as much filtering surface as the conventional depth-type filters.

fume hoods, and means for disposal of radioactive wastes. The benefits of consultation with University personnel also were present.

Using radioisotopes, the process set up by AC engineers involved (a) preparing radioactive resin, (b) impregnating the filter paper with the radioactive resin, (c) curing the paper to definite known degrees of cure, (d) circulating lubricating oil through the filter, (e) measuring the radioactivity of the lubricating oil, and (f) comparing this activity against the activities of oils containing known amounts of the same radioactive resin.

Preliminary Work Required

In radiochemical work, a relatively large amount of preliminary work with radiostable materials is required as compared with the actual work with radioactive materials. It was necessary to work out the following problems with radiostable materials before any work with radioisotopes could be initiated:

(a) Synthesis of the radiostable resin in laboratory batches until familiarity with the procedure is established and the resin which is produced repeatedly meets specifications. In the meantime, changes in the procedure are made as may be required to eliminate, during the subsequent radioactive run, the possibilities of spillage of reactants or products, dissemination of radioactive fumes into the atmosphere, and contamination by radioactive materials of work space, person, clothing, or nucleonic counting equipment.

(b) Evolution of the procedures for curing the elements to prescribed amounts of cure and to secure reproducible cures. Also included is the problem of disposal of fumes evolved during curing since these conceivably may be radioactive.

(c) Development of methods for determining degree of cure.

(d) Designing of equipment to circulate oil through the test elements and for measuring the radioactivity of the oil.

(e) Determination of the quantitative utilization of the reactants used to prepare the oil-filter resin.

Tests with radiostable resin established that for 2 kg of radioactive resin about 5 millicuries of carbon-14 (radioisotope of carbon) would be needed. The carbon-14 could be introduced into the resin by preparing the radioactive resin using either radioactive phenol or radioactive formaldehyde.

Since the finished filter-element resin has a phenolic odor, it is evident that the utilization of phenol is not quantitative. Therefore, if 5 millicuries of radiophenol were used in the resin preparation, the resulting resin would have less than 5 millicuries of activity upon curing and removal of the excess phenol. The vapors emitted on curing would almost certainly be radioactive.

On the other hand, utilization of formaldehyde was found to be virtually quantitative so that 5 millicuries of formaldehyde would produce 5 millicuries of cured resin. Consequently, the curing operation would not evolve vapors of more than a very low level of radioactivity. Therefore, the use of radioformaldehyde instead of radiophenol was indicated. In addition to this absence of radiological danger which was the dominating factor, the economics also were in favor of radioformaldehyde since it was available at a substantially lower cost than radiophenol.

Authorization was received by the University of Michigan from the A.E.C. Isotopes Division at Oak Ridge, Tennessee, to purchase a quantity of the radioformaldehyde from a private concern. The resin was synthesized and its characteristics were identical, except for its radioactivity, with the Aluvac resin. Oil-filter elements were prepared using the radioactive resin and were processed to

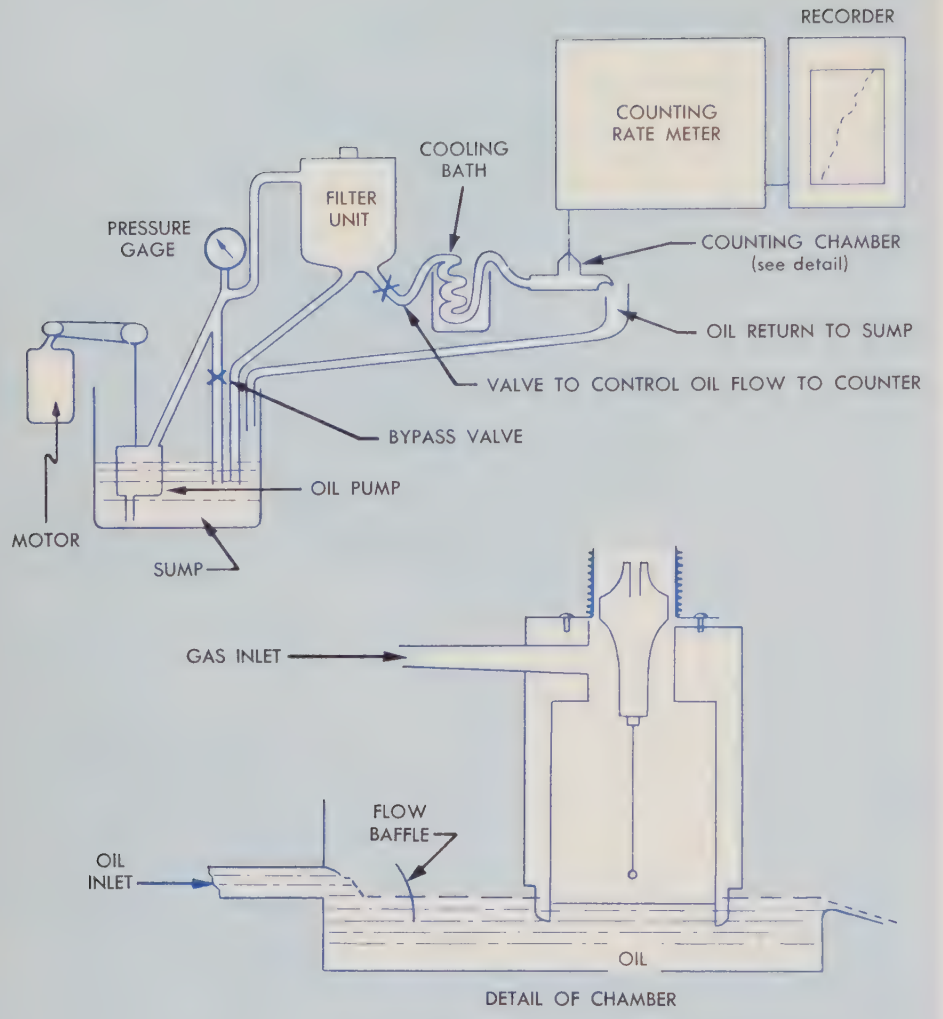

Fig. 2—Drawing of the apparatus used to measure the radioactivity levels of the carbon-14 in the lubricating oil. The counting chamber from a gas-flow counter (bottom) was placed in the lubricating-oil system as shown (top). The counting gas bubbled out from under the edge of the counting chamber. Standardization of the apparatus was accomplished by adding 1-gm aliquots of the tagged resin to the circulating oil.

known degrees of cure—the cures being reproducible to ±0.7-cure percentage unit. As expected, the gases evolved during curing were of a very low order of radioactivity and, after completion of the project, the oven needed a minimum of decontamination to be made radiologically safe.

Test Apparatus

The resin was tested by using a gas-flow counter as a semi-dip counter. Originally, the multiple-sampling technique was contemplated; however, this was abandoned in favor of the more sensitive method of continuous counting of a branch stream of the oil using a dipping gas-flow windowless counter. This device recorded the counts on a suitably damped d-c recording milliammeter which was fed from a count-rate meter[1] (Fig. 2).

Test Results

At 190° F lubricating oil temperature, it was found that cures somewhat below the established cure imparted no appreciable radioactivity to the oil and, therefore, no appreciable amount of resin was being eluted. Furthermore, resin curing occurs at this temperature so that, after a few hours, a filter element originally at the lower cure reaches the originally established cure percentage. Uncured resin, of course, imparted considerable radioactivity to the oil. At 150° F lubricating oil temperature, resin removal is inappreciable above a relatively low degree of cure. In the manufacture and sale of Aluvac elements, however, the most adverse service conditions must be considered as the normal design criteria. Consequently, in practice, a large safety factor is allowed and the minimum cure specification was set considerably higher than the point at which resin is first detected in the oil under the most adverse circumstances of temperature.

The final criterion is, of course, the behavior of the filter in service. To protect the customer fully, the originally established cure percentage is still the specification until road service tests, now in progress, confirm the radiochemical evidence that the lower cure is absolutely safe for automotive or Diesel engines and their lubricating oils.

Conclusion

This application of radioisotopes to an oil-filter manufacturing problem is only one case solved through the use of radiochemistry. Direct application of radioactive isotopes to industrial problems is potentially as broad and as varied as the industrial field itself.

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A Commentary on the Technical Boundaries Within Which the Patent System Functions

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According to the ancient adage, necessity is the mother of invention. However, necessity is, at best, a matter of degree, ranging from the absolutely indispensable to the highly artificial products of desire. With respect to the latter, it is significant that most of the major inventions of the past, such as the steam engine and the telephone, were regarded as mere toys when invented but ultimately became necessities in the popular sense of the word. In any case, whether necessity be vital or artificial, the inventor's thinking is always prompted by a temporary inability to solve a technical problem.

BROADLY speaking, an invention is the means or instrumentality by which a problem is overcome. The exercise of invention is a two-stage mental process of, first, recognizing a problem, and second, finding a solution for it—or recognizing what needs to be done and discovering how to do it. Merely recognizing a problem is not invention, nor is it invention to suggest a desired result. However, the value of recognizing a problem should not be underestimated. Although in the usual case the problem or need is obvious while the solution is unobvious, not infrequently the problem or need is far from obvious while the solution is self-evident, once the need is recognized. For example, it may be considerably more difficult to determine why a certain engine component fails than it is to provide a solution, once the true cause of failure is identified. However, it will be noted that in either case both recognition and solution are still essential—the sole difference being the relative difficulty of each.

Although problem and solution are fundamental prerequisites of every invention, it should not be assumed that recognition and solution of every problem involves invention, for in many cases both the problem and solution are obvious. Similarly, just as the solutions to some problems fail to amount to invention, some inventions do not meet the requirements of patentable invention. Consequently, even when the solution of a problem involves mental processes which are neither natural nor obvious, the result may not be patentable. Whether an invention is or is not patentable is determined primarily by reference to the patent statutes and judicial decisions. Following are some of the many reasons militating against patentability of inventions together with a brief explanation of each. It will be understood that this list is representative only and is not intended as a comprehensive treatment of the subject.

Non-Statutory Subject Matter

Patents are not granted for all new and useful inventions or discoveries. Patentable subject matter is limited to "new and useful processes, machines, manufacture or compositions of matter or any new and useful improvement thereof . . ." Examples of non-statutory subject matter are:

(a) Methods of doing business
(b) Scientific principles
(c) Naturally occurring articles.

Methods of Doing Business

In spite of the ingenuity of some methods of doing business, they are excluded as a class from patent protection. Thus, although the "self-service" system employed in most present-day super markets has virtually revolutionized this type of retail marketing, it could not be patented since it involves merely giving the customer access to the merchandise. By way of distinction, however, where novel physical structures, such as automatic shelf loaders are employed to implement the method of doing business, patentable invention may result.

Scientific Principles

Scientific principles in the abstract are unpatentable, although patents are granted for useful applications of such principles. However, it is the method of employing the principle or the device in

A scientific principle is not patentable but a device using the principle may be

which it is embodied which is patentable and not the principle or theory which explains the operation. For example, while the discovery and explanation of a geometric principle does not amount to invention, an automotive suspension system employing the principle to beneficial or useful purpose may be inventive.

Naturally Occurring Article

A naturally occurring article is that subject matter which has always existed in nature or in its natural state, even though its value or even its existence has not previously been recognized. By way of illustration, one may discover that a certain mold possesses remarkable medicinal properties. Valuable as this discovery may be, the mold *per se* is unpatentable, although the process of preparation may be. Thus, although Fleming first isolated and determined the antibiotic properties of pencillin, only the process for manufacturing it could be patented.

Other Non-Patentable Inventions

Wholly apart from the specific classes of subject matter which may not be the subject of a patent, there are numerous other inventions which, while not in the excluded classes, are nevertheless unpatentable for other reasons set forth in the statutes and decisions. Examples of these follow.

No Useful Purpose

As a prerequisite to patentability, an invention must be useful. Therefore, by implication, an invention having no useful purpose is unpatentable. In this connection, it is interesting to note that the United States Patent Office consistently rejects applications for patents on perpetual-motion machines on the grounds

that such machines have no useful purpose. The reasoning behind this is that, since perpetual motion is scientifically impossible, the machine can not work and, therefore, has no useful purpose. Other types of inventions excluded under the broad meaning of the term are those which are frivolous, injurious to the public health or morals, require commission of a crime, or are against public policy. Perhaps the most familiar of this class are the familiar cartoon gadget inventions. Ingenious though they may be, such curiosities serve no intelligent purpose within the accepted meaning of the term and are, therefore, deemed frivolous.

Obvious Subject Matter

The patent statutes also provide that a patent may not be obtained where the difference between the subject matter sought to be patented and the prior art is such that it could be made by a person having ordinary skill in the art to which the subject matter pertains. This distinction, however, is most difficult to apply, since no one has yet succeeded in defining what degree of skill amounts to ordinary skill.

Bars Effective Against Patentable Subject Matter

Even when an invention avoids the foregoing classes of subject matter and types of invention, it may still be unpatentable for reasons of anticipation or priority.

Previously Patented

Since patents are granted only to the first inventor, the existence of a previous patent precludes the second inventor, even though his invention was made with no knowledge of or reference to the first invention. In this regard, it is important to note that the previous patent need not be a United States patent but may be a patent anywhere in the world.

Printed Publication

If the invention was described in a printed publication anywhere in the world more than one year prior to the application, a patent may not be obtained.

Public-Use Bar

If the inventor waits for more than one year after the first sale, public knowledge, or public use of the invention by himself or others, he is barred from obtaining a patent. The public-use bar, however, applies only to use in the United States. Knowledge of or use in a foreign country even for more than one year does not bar an application for patent in the United States.

Interference

Occasionally, two or more inventors more or less contemporaneously invent the same thing. If both apply for a patent, the applications may be placed in interference in the United States Patent Office to determine the question of priority. Since only one can be the first inventor, the other is precluded from obtaining a patent. In interference proceedings the question of "reduction to practice" becomes most important. It will be recalled that invention was defined as the instrumentality or means by which a problem is overcome, while the exercise of invention refers to the mental acts of conception. In determination of priority, under certain circumstances the party first reducing the invention to practice may be deemed the first inventor, even though the opposing party was first to conceive the invention. A reduction to practice may be either actual or constructive, the latter being evidenced by the filing of a patent application.

Conclusion

In spite of the numerous limitations mentioned and the large number of patents already issued, the potential field of invention is today much greater than at any time in the past and will continue to increase in the future. Although, at first impression, it might seem that patentable subject matter will ultimately be exhausted, history clearly demonstrates that the opposite is true. Inventions, in fact, beget inventions. Each of the basic inventions of the past, as well as numerous secondary inventions, has fostered great numbers of improvement patents. Although the possible number of improvements in a particular narrow field may be limited, technological advancement resulting in part from the aggregate of patented inventions makes possible further basic inventions which, in turn, reopen the opportunity for still further improvement patents. Consequently, each new patent should be regarded not as one less opportunity for invention, but as one of a series of keys which collectively unlock the frontiers of increased opportunities for further invention.

Notes About Inventions and Inventors

On this and the following pages are listed some recent patents granted to General Motors prior to June 1. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

Patents Granted

Rudolph E. Busch and Emerson L. Kurtzwarth, *Ternstedt Division, Detroit, Michigan, for a Polishing Buff Wheel, No. 2,668,398, issued February 9.* This patent relates to a buffing wheel made from discarded buffing pads. The salvaged pads are cut and shaped for folding over one or more rigid rings that may be clamped together to form a composite buffing wheel.

Mr. Busch is senior project engineer in the Process Engineering Department of Ternstedt. He was initially employed in 1932 as an assembler in the Plating Department. In 1937 he was made a chemist-analyst, and, in 1942, became an assistant X-ray technician. He was promoted to general supervisor of the X-ray Test Laboratory in early 1945, and to his present position in September 1945. His projects include work on a photographic process for template making and a method of reclaiming polishing belts.

Mr. Kurtzwarth is an analyst in the Cost and Financial Analysis Department of Ternstedt, serving in this capacity since 1943. He joined the Division in 1927 as an engineer in the Engineering Department and subsequently held the positions of assistant supervisor of Time Study and Cost Analyst (Plant Operation). His previous projects have included work on buffs and compounds which has led to the granted patent listed above. He served in World War I as a Naval Air Force ensign and was an engineer with several Detroit firms prior to joining Ternstedt.

William F. Darin and Joseph J. Palid, *Ternstedt Division, Detroit, Michigan, for a Spring Winding Machine, No. 2,668,349,*

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issued February 9. This patent is on a machine employing a reciprocating carriage to transfer a spiral spring from a stack to a reciprocating ram which winds the spring by passing it through a helically slotted cylinder, the improvement being principally in the spring supporting means on the carriage.

Mr. Darin is assistant superintendent of tool rooms at Ternstedt. His GM employment covers a period of more than 27 years, with most of his work related to the manufacturing operations of the Division. He began as an errand boy in 1927, progressing to die maker, foreman, production engineer, and supervisor of production engineering. He assumed his present position in 1952. Work on a spring winder has resulted in the patent listed above.

Mr. Palid has been senior production engineer at Ternstedt since 1952. A year after joining the Division in 1936 as an apprentice in the Millwright Department, he attended General Motors Institute, studying industrial engineering. He earned his diploma from G.M.I. in 1940. In 1948 Mr. Palid received the B.S. degree in mechanical engineering from Wayne University in Detroit. Mr. Palid is a member of the American Society of Tool Engineers and Alpha Tau Iota, honorary G.M.I. engineering fraternity.

A. William Sundwick, *Ternstedt Division, Flint, Michigan, for a Die-Casting Machine, No. 2,671,936, issued March 16.* This invention involves an insulating construction within a die block of a die-casting machine for thermally insulating the nozzle from the die blocks to insure proper solidification of the casting metal in the die cavity.

Mr. Sundwick has been engineer-in-charge of the Process Engineering Department of Ternstedt, Flint, since 1950. He joined the Division's Manufacturing Department at Detroit in 1936 after earning the B.S. degree in chemical engineering from Michigan College of Mining and Technology. He is a member of the Die Casting and Die Casting Alloys Committee of the American Society for Testing Materials and of the Electroplating Committee, American Electroplaters Society.

Earl W. Jorolemon, *Delco Appliance Division, Rochester, New York, for a Warm-Air Furnace and Radiator Construction, No. 2,672,858, issued March 23.* This patent relates to a hot-air furnace with a new radiator portion which provides maximum heat transfer.

At the time of his retirement in 1953, **Mr. Jorolemon** was an engineer in the Engineering Department of Delco Appliance. He joined the Division in 1922 in this same Department. For a period of six years he was in charge of engineering and served as a building superintendent. Before coming to General Motors, Mr. Jorolemon was employed as a draftsman.

James W. Light* and Robert C. Treseder,* *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Biasing-Type Electronic Synchronizer, No. 2,673,309, issued March 23.* This patent relates to an electronic system for effecting synchronous operation of a number of engine-propeller combinations. The combinations can either be synchronized with a master reference speed source, or be synchronized to one of the engine-propeller combinations as the master with the remaining combinations as slaves.

Richard M. Goodwin,* *Delco-Remy Division, Anderson, Indiana, for an Armature Assembling Machine, No. 2,673,391, issued March 30.* This patent deals with an armature assembling machine wherein the core laminations are automatically oriented and then assembled on a shaft.

*Biographies of inventors marked with an asterisk in this section have been published in previous issues of the GENERAL MOTORS ENGINEERING JOURNAL.

Richard M. Goodwin,* *Delco-Remy Division, Anderson, Indiana, for an Assembling Machine, No. 2,676,394, issued April 27.* This patent relates to a machine for assembling a sleeve within the axial bore of a commutator segment assembly.

Wesley S. Erwin and Walter E. Sargeant, *Research Laboratories Division, Detroit, Michigan, for a Rectified Current-Supply System, No. 2,674,713, issued April 6.* This patent relates to a battery-charging system employing a magnetic amplifier and which may be used as a car equivalent ignition source during vehicle dynamometer tests.

At the time of his death in 1952, **Mr. Erwin** was employed in the Physics and Instrumentation Department of the Research Laboratories. He received his undergraduate training at University of Cincinnati and the M.S. degree in 1942 from University of Cincinnati, School of Applied Science. Some of Mr. Erwin's past projects at the Research Laboratories have included work on a silver bearing-bonding process and the use of ultrasonics for non-destructive testing of bonds, the latter leading to the development of the Sonigage for measuring blind-wall thickness.

Mr. Sargeant is a special problems and consultation engineer in the Physics and Instrumentation Department of Research Laboratories. Currently, he is engaged in an investigation of the possible uses of transistors. His work at the Research Laboratories has resulted in four granted patents. Mr. Sargeant received the B.S. degree in electrical engineering from University of Michigan in 1926.

Clarence E. Frank, *Chevrolet Motor Division, Detroit, Michigan, for a Suspension System, No. 2,674,450, issued April 6.* This concerns an arrangement of the conventional U-shaped, transverse, torsion stabilizer bar so that its crank arms coact with the bump and rebound limiting cushion members on the vehicle frame.

Mr. Frank serves as a project engineer in the Central Office of Chevrolet Motor. Since his original employment with Chevrolet Motor as a draftsman in 1926, he has seen service with the Research Laboratories, the Cleveland Diesel Engine, and the Detroit Diesel Engine Divisions. His current major project is concerned with power steering for Chevrolet trucks. Mr. Frank is a member of the Society of Automotive Engineers.

Knut O. Keel, *Cleveland Diesel Engine Division, Cleveland, Ohio, for a Drive and*

Control System, No. 2,674,355, issued April 6. This patent covers an improved, manually responsive, maneuvering control system for the engine speed and ahead and astern drive clutches of a marine vessel.

Mr. Keel is government contract sales manager of Cleveland Diesel Engine. Since his employment in 1920 as a test engineer, he has been promoted through several positions, becoming chief engineer in 1936, a position which he held until assuming his present position. His work with Diesel-engine design has led to four patents. Among the societies of which Mr. Keel is a member are the S.A.E. and the American Society of Mechanical Engineers.

James H. Wernig, *Fisher Body Division, Detroit, Michigan, for a Closure Weather Strip, No. 2,674,487, issued April 6.* This patent is on a strip for sealing automobile deck lids and the like which is so formed as to more securely thread itself onto its mounting flange under the force of sealing pressure.

Mr. Wernig serves as chief engineer of Fisher Body's Engineering Division. In 1936 he joined the Body Engineering Department of Fisher Body as assistant chief draftsman, was promoted to body engineer in 1941, to division engineer—aircraft structure in 1943, to assistant chief engineer in 1944, and to his present position in 1949. Ten granted patents have resulted from Mr. Wernig's work in body design and engineering.

William J. Adams, *Euclid Division, Cleveland, Ohio for a Bowl and Apron Control For Carry-Type Scrapers, No. 2,674,815, issued April 13.* This is a carry-type off-the-road scraper wherein the pivotal connection between the pull yoke and the scraper bowl is arranged in the manner whereby the digging load on the scraper blade is transferred to the tractor wheels in a more efficient manner.

Mr. Adams is senior development engineer in the Product Engineering Department at Euclid. His contribution to scraper (self-loading earth-moving machinery) development dates from the middle 1920's when he was instrumental in perfecting the load-carrying front apron now used on every scraper model. In 1927 Mr. Adams designed and manufactured the first successful carry scraper and front apron combination for use with a pulling tractor. Mr. Adams joined Euclid in 1947 where his developments have included the Euclid four-wheel

scrapers and the large rubber-tired tractors used to pull them.

John Dickson, *Detroit Diesel Engine Division, Detroit, Michigan, for a Camshaft, No. 2,674,904, issued April 13.* This patent relates to journalling Diesel-engine camshafts to accommodate beam-wise flexure resulting from eccentric loads imposed by their end-mounted counterweights.

John Dickson, *Detroit Diesel Engine Division, Detroit, Michigan, for a Cylinder-Head Gasket Construction, No. 2,679,241, issued May 25.* This patent pertains to a gasket construction between the cylinder head and cylinder block of an internal-combustion engine. The cylinder head is flexed slightly to apply uniform pressure to the gasketed areas adjacent the various engine passages.

Mr. Dickson has been chief design and development engineer at Detroit Diesel Engine since 1950. He has been associated with the design and manufacture of Diesel engines for 35 years and 14 patents have been granted as a result of his work. Mr. Dickson is a graduate of the Royal Technical College of Glasgow, Scotland. He is vice president of the Diesel Engine Activity of the S.A.E.

Ronald K. Evans and William H. Manning,* *Central Office, Detroit, Michigan, for an Internal-Combustion Engine, No. 2,674,988, issued April 13.* This patent covers an improved jelly-glass-type unit cylinder-to-crankcase clamping arrangement, and resilient mounting for the cylinder's removable liner.

Mr. Evans was an executive vice president and director of GM from 1950 until his retirement August 31. In 1920 he joined Remy Electric Company (which later became Delco-Remy Division of General Motors) and left four years later to become a field representative of the General Motors Export Company. Since that time he also served as regional director for Europe, as managing director of Vauxhall Motors, Limited, in England, and as general manager of Adam Opel in Germany.

Arthur W. Gaubatz,* Charles J. McDowall, Otakar P. Prachar, and John B. Wheatley,* *Allison Division, Indianapolis, Indiana, for a Turbine or Compressor Rotor, No. 2,675,174, issued April 13.* This patent relates to a composite rotor for an axial-flow compressor. Rotor discs for each stage have their rims in abutting relations and splined together for transmission of torque and are held assembled by a central tie bolt.

Arthur W. Gaubatz, *Allison Division, Indianapolis, Indiana, for a Combustion Chamber with Crossover Tubes, No. 2,679,136, issued May 25.* This patent covers an improved gas-turbine combustion apparatus with a crossover tube structure to connect individual combustion chambers that can be easily installed and removed, facilitating repair or inspection of the engine.

Mr. McDowall serves as chief—turbine components in the Aircraft Engineering Department of Allison. In 1927 he was granted the B.S.M.E. degree from University of Florida. His General Motors career began in 1932 when he was initially employed by Allison as a junior engineer. He is presently engaged in the development of controls and combustion for the T-40, T-56, and J-71 engines. Mr. McDowall is a member of the Aircraft Engineering Division of the S.A.E. and has previously served on several S.A.E. and N.A.C.A. committees.

Mr. Prachar serves as head of the Research Group in the Aircraft Engineering Department of Allison. Since his original employment with Allison in 1940 as a test engineer he has held the positions of performance division head and senior project engineer. Mr. Prachar received the B.M.E. degree from University of Minnesota in 1934 and the M.S. degree from the same school in 1936.

Arthur F. Underwood,* *Research Laboratories Division, GM Technical Center, Detroit, Michigan, for a Fuel-Injection Pump, No. 2,674,950, issued April 13.* This patent has to do with providing the pressure-chamber end of the pump plunger with a cavity wherein the fuel acts to expand it against the chamber side walls, thereby reducing blow-by and obtaining better lubrication of the sliding surfaces.

Cloyd L. Betzer, *Delco Appliance Division, Rochester, New York, for a Fluid Fuel Furnace and Antipuffing Means Therefor, No. 2,675,865, issued April 20.* The invention disclosed in this patent relates to a domestic furnace of the oil-burning-type

having an air-supply sleeve and burner-tube construction which eliminates occurrence of the condition known as "puffing."

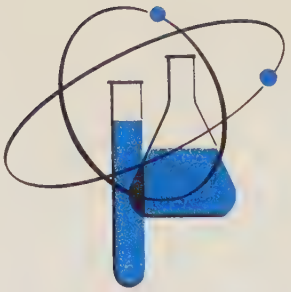
Mr. Betzer is a Divisional heating engineer in the Engineering Department of Delco Appliance. Prior to employment by General Motors in 1948, he served as assistant to the vice president in charge of manufacturing of the Krypton Corporation. Mr. Betzer earned the mechanical engineering degree in 1939 from Cornell University.

Joseph B. Bidwell, *Research Laboratories Division, GM Technical Center, Detroit, Michigan, for a Load-Measuring Apparatus, No. 2,675,701, issued April 20.* This patent relates to load-measuring apparatus for measuring both static and dynamic tension and compression loads of a fatigue machine. The apparatus utilizes strain-sensitive impedance means mounted on a pre-calibrated deformable testing head, the impedance means being connected into an electrical bridge to provide a load diagram on the face of an oscilloscope.

Mr. Bidwell serves as assistant head of the Mechanical Development Department of the Research Laboratories. He first entered the employment of that Division in June 1941 as a summer student. In June 1951 he was promoted to his present position which involves research in the field of bearings and lubrication. He is a member of the S.A.E., the Sigma Xi honorary society, and serves on the Research Advisory Committee of the American Society of Lubrication Engineers. Mr. Bidwell received the B.S.M.E. degree from Brown University in 1942.

William F. King and Thomas C. VanDegrift,* *Research Laboratories Division, GM Technical Center, Detroit, Michigan, for a Torquemeter, No. 2,675,700, issued April 20.* This invention relates to torque-measuring means having two alternating-current generators displaced from each other along a loaded member with adjustments for indicating movement of one to give torque readings.

Mr. King serves as supervisor of the Electro-Mechanical Section of the Special Problems Department, Research Laboratories. In 1936 he was employed by Fisher Body Division as a co-op student. In 1939 he transferred to the Research Laboratories where he was promoted to senior project engineer in 1949 and to his present position in 1953. Mr. King graduated from General Motors Institute



in 1940 and was granted the B.S. degree in mechanical engineering from University of Michigan in 1941.

Clovis W. Lincoln,* *Saginaw Steering Gear Division, Saginaw, Michigan, for a Steering Gear, No. 2,675,715, issued April 20.* This patent relates to double drag link-type steering gears and the improvement embodies means for eliminating play and backlash between the teeth of the gears for operating the pitman arms thereof.

Wesley W. McMullen, *AC Spark Plug Division, Flint, Michigan, for a Filler Pipe Cap Provided With Filter Assembly, No. 2,675,886, issued April 20.* This patent relates to a filter assembly in the form of a removable closure on the oil-filler tube leading to a crankcase, the filter element being easily replaceable and a tight seal being provided to insure dust removal from ventilating air entering the crankcase.

Mr. McMullen is an experimental engineer in the Automotive Engineering Department of AC Spark Plug. He earned the B.S. degree in mechanical engineering from University of Michigan in 1934. In July of the same year he joined the Division as a student engineer-in-training in the Personnel Training Department. This is the first patent resulting from Mr. McMullen's work with intake-air cleaners and silencers.

Richard J. Brittain, Jr.,* *Hyatt Bearings Division, Harrison, New Jersey, for a Journal Box, No. 2,676,854, issued April 27.* This patent relates to a railroad journal-box construction wherein a thrust block engageable with the end of an axle yieldably receives the end thrusts of the axle through a conical, resilient, rubber-like member that distorts under shear deformation to cushion the end thrust of the axle. The rubber member has inner and outer metal sleeves bonded thereto to control shear deformation under stress.

Gordon H. Diehl and Robert M. Hopkins, *Delco Appliance Division, Rochester, New York, for a Turbulator, No. 2,676,649, issued April 27.* This patent relates to a turbulator construction for an oil burner. The principal feature of the turbulator is to effect a turbulent air flow which completely envelopes the cone of atomized fuel produced by an atomizing nozzle.

Mr. Diehl is an application heating and air conditioning engineer in the Engineering Department at Delco Appliance. Since his original employment by Delco Appliance in 1930 as an assembler, he has advanced to his present position by steady promotions. He received the B.M.E. degree from General Motors Institute in 1953. Mr. Diehl is a member of the National Warm Air Heating and Air Conditioning Association.

Mr. Hopkins is a senior engineer with Delco Appliance. Currently, he is supervisor of the Heat Laboratory dealing with the testing and development of general, domestic heating equipment. Mr. Hopkins received the B.S. degree from State Teachers College of Oswego, New York, in 1941. He is a member of Epsilon Pi Tau.

William A. Fletcher,* *Delco-Remy Division, Anderson, Indiana, for a Strip Feeding Mechanism, No. 2,676,799, issued April 27.* This patent deals with a mechanism for feeding sheet-metal strip material at different rates whereby a series of operations may be performed thereon.

James W. Jacobs* and Keith K. Kesling, *Frigidaire Division, Dayton, Ohio, for a Refrigerating Apparatus, No. 2,676,727, issued April 27.* This patent concerns a non-metallic breaker strip interposed between a refrigerator-cabinet outer wall and the food-storage-compartment liner which is secured to the cabinet by a specially designed slip-in spring clip, thereby eliminating the use of screws and their exposed heads about the compartment front opening.

Mr. Kesling is project and design engineer in the Research and Future Products Engineering Department of Frigidaire. Originally employed in 1944 as a junior clerk in the Tool Design Department, Mr. Kesling advanced through regular promotions to appointment to his present position in 1951. He attended University of Dayton and Dayton Art Institute. This is the first patent granted as a result of Mr. Kesling's work with refrigerator-cabinet design.

Earl P. Miller, *Fisher Body Division, Detroit, Michigan, for a Work-Removing Apparatus, No. 2,677,342, issued May 4.* This invention relates to hydraulically operated work-removing arm mechanisms

having improved carriage and operating linkage and more efficient gripping jaws.

Mr. Miller serves as senior production engineer in the Master Mechanics Department of Fisher Body. He was originally employed by Fisher Body in 1927 as a die maker. In 1931 he was made foreman, in 1937 general foreman, in 1942 superintendent, and in 1944 senior production engineer. Mr. Miller is currently working with the development of automation devices.

Max G. Bales,* *Delco-Remy Division, Anderson, Indiana, for an Ignition Distributor, No. 2,678,365, issued May 11.* This invention is directed to ignition systems and particularly to rotors for use in distributors in ignition systems wherein the rotor is designed to eliminate ignition interference from radio sets.

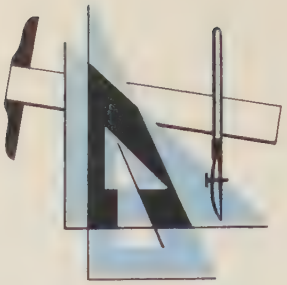
William F. Brundage and Joe White, *Delco-Remy Division, Anderson, Indiana, for a Method of Assembling Electromagnetic Horn, No. 2,677,875, issued May 11.* This patent deals with an electromagnetic horn and is particularly directed to a method of setting the air gap between the horn-motor magnet poles and the motor armature.

Mr. Brundage is supervisor of the Technical Data Section of the Engineering Laboratories of Delco-Remy. He was originally employed by Delco-Remy as a blueprint boy in 1929. In 1931 he was transferred to the horn laboratory where he became section head in 1936, a position which he held until he assumed his present duties in 1949.

Mr. White is section head on horns in Delco-Remy's Engineering Department. He joined the Division in 1926 as a student engineer after earning the B.S. degree from Rose Polytechnic Institute. He was promoted to his present position in 1933. His work with automobile horns has resulted in 11 granted patents.

Howard Carson and Howard M. Geyer,* *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Propeller De-icing Control System, No. 2,678,181, issued May 11.* This patent relates to a propeller de-icing control system. The principal features of this invention reside in the cyclic energization of the blade heating elements, and an electrical circuit for the heating elements whereby failure of one heating element will cause de-energization of all heating elements.

Mr. Carson is no longer with the Division.



Carl L. Clevenger, William A. Fletcher,* Charles A. Nichols,* and Forest L. Zion, *Delco-Remy Division, Anderson, Indiana, for a Manufacture of Commutators, No. 2,677,874, issued May 11.* Disclosure of this patent is directed to a method of making commutators for dynamoelectric machines wherein assembly of a plurality of commutator bars is accomplished through the use of a tubular rivet which is shortened by heat and pressure during the assembly operation.

Mr. Clevenger is a senior engineer at Delco-Remy. He joined the Division 21 years ago as a utility man. In 1942 he was promoted to foreman and one year later was promoted to senior engineer, his present position.

Mr. Zion is a special machine builder at Delco-Remy. Thirty-one years ago he joined the Division as a tool machinist. In 1941 he was promoted to his present position.

Raymond C. Davis,* *Inland Manufacturing Division, Dayton, Ohio, for a Rotary Fan, No. 2,678,104, issued May 11.* This patent relates to a fan structure wherein a blade-carrying hub is resiliently connected to a motor-driven hub by means of a plurality of spaced rubber blocks that are secured in registering apertures in each of the members so that the blocks will transmit rotation between the members and isolate motor vibrations from the fan.

James R. Edwards, *Delco-Remy Division, Anderson, Indiana, for a Feeding Apparatus, No. 2,678,138, issued May 11.* This patent is directed to a feeding device for feeding briquettes of powdered material along a supply chute wherein the briquettes are fed intermittently a predetermined distance from a feeding station.

Mr. Edwards is a senior engineer at Delco-Remy. He joined the Division in 1936 as an electrician; was promoted to engineer in 1943 and to senior engineer, his present position, in 1950. Mr. Edwards studied industrial engineering at General Motors Institute, Flint, Michigan. He is a member of the American Institute of Electrical Engineers.

Bernard E. Frank,* Rea I. Hahn,* and Donald P. Worden,* *Rochester Products Division, Rochester, New York, for a Tube Cutting Apparatus, No. 2,678,097, issued May 11.* This patent is directed to a device for cutting tubing into equal lengths without stopping movement of the tubing. A carriage has a clamp for gripping the tubing to move with it and a shear blade supported on the carriage cuts the tubing, the blade being operated by a cam in response to movement of the carriage.

Millard E. Fry,* *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,678,379, issued May 11.* This patent discloses a control for reducing the heating rate of the surface heater of an electric range when water boiling occurs in which the rise in temperature of a lagging bimetal to the same temperature of another bimetal in good contact with the vessel causes the switching from a high heat circuit to a low heat circuit when boiling occurs.

Thomas B. Martin and James R. May, *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Propeller-Pitch Control, No. 2,678,103, issued May 11.* This patent is directed to a variable-pitch propeller and particularly to control pitch changes in both positive and negative pitch ranges and to effect feathering and unfeathering. A governor valve controls both positive and negative pitch changes and a manually operable valve functions to control the governor valve to shift from positive to negative pitch. A main pump is operative to effect pitch change to correct relatively small speed errors and an auxiliary pump becomes effective to aid the main pump if the corrected speed error is relatively great. An accumulator is effective to effect feathering and unfeathering operations.

Mr. Martin is no longer with the Division.

Mr. May serves as chief of engineering services with Allison. Since his original employment in 1941 as a junior draftsman, he has advanced steadily through the positions of assistant project engineer, project engineer, and senior engineer. During this time, his work has resulted in three granted patents related to propellers and propeller mechanisms. Mr. May earned the B.S.M.E. degree from Purdue University in 1941.

Karl Schwartzwalder and Robert W. Smith,* *AC Spark Plug Division, Flint,*

Michigan, for a Ceramic Contact Resistor Composition, No. 2,679,568, issued May 25. This patent relates to a resistor unit of glass-bonded resistance material and having contacts formed of metal powder bonded by borosilicate glass.

Mr. Schwartzwalder serves as chief ceramic engineer in the Ceramic Laboratory of AC Spark Plug. His work with ceramics and metal has resulted in 23 patents. He received his B.Cer.E. degree from Ohio State University in 1930 and his M.S. degree from the same school in 1931. Mr. Schwartzwalder is a member of the S.A.E. and the American Ceramic Society.

Wilfred A. Bychinsky, *AC Spark Plug Division, Flint, Michigan, for a Spark-Plug Tester, No. 2,679,627, issued May 25.* This invention relates to an electric contact-arm mounting for a spark-plug tester which employs a single spring to bias the contact arm into contact with the spark plug and retain the pivot pintle in position.

Dr. Bychinsky is chief ignition engineer in the Spark Plug Engineering Department of AC Spark Plug, a position which he has held since 1944. His work with spark plugs and ignition systems has resulted in 10 patents. Dr. Bychinsky received the B.S.E.E. degree from University of Michigan in 1930, followed by the M.S.E. degree in 1931 and the Ph.D. degree in 1933 from the same school.

Charles W. Miller and George W. Onksen, Jr.,* *Guide Lamp Division, Anderson, Indiana, for a Light-Responsive System, No. 2,679,616, issued May 25.* This invention discloses a light-responsive system for controlling the dimming of automobile headlights actuated and de-actuated at different light intensity levels.

Mr. Miller is a project engineer in the Engineering Department at Guide Lamp. His General Motors employment began when he was originally employed at that Division in 1928 as an inspector. He studied electrical engineering at Purdue University and, in addition, took correspondence courses through the Radio and Television Institute. Mr. Miller's major assignments have been concerned with the development of the Autronic-Eye automatic headlamp control. He is currently engaged in developmental work on improvements of this device. He is a member of the Radio and Television Service Engineers, Inc.

John M. Haldeman, *Buick-Oldsmobile-Pontiac Assembly Division, Linden, New Jersey, for a Process for Honing Piston Rings, No. 2,679,129, issued May 25.* This invention involves a method of honing piston rings wherein the rings are honed while being held rigidly in a stack and then released so that the rings may expand within the stack. The rings and hone are relatively rotated and reciprocated in various ways while the process is being carried on.

Mr. Haldeman is superintendent of the Chassis Department of B.O.P. Assembly. He joined General Motors in 1940 as a student trainee at Allison Division. In 1946 he transferred to the Process Development Section of the Manufacturing Staff as a project engineer and in 1952 transferred to his present Division. He earned the B.M.E. degree from General Motors Institute in Flint, Michigan. Mr. Haldeman's previous work on the development of steel piston rings has resulted in one granted patent with many others pending.

Joseph Rawley, *Buick Motor Division, Flint, Michigan, for an Electrical Terminal Block, No. 2,679,634, issued May 25.* This invention relates to a terminal block having terminal screws loosely mounted therein for ready assembly and a resilient strip acting between the block and the underside of the screwheads to prevent accidental loss of the screws.

Mr. Rawley serves as staff engineer in the Chassis Drafting Section of Buick Motor's Engineering Department. His initial employment with General Motors was as a layout draftsman in the Air Filter Department of AC Spark Plug Division in Flint. Two years later, Mr. Rawley transferred to Buick Motor as chief draftsman. This is the second patent granted as a result of his work.

Earl W. Reinsch, *Moraine Products Division, Dayton, Ohio, for a Separator, No. 2,678,731, issued May 18.* This patent is directed to a separator which can be used as a means for removing dirt particles from lubricating oil in internal-combustion engine lubricating systems. The device is basically a centrifugal-type separator operating on a full-flow principle placed within the oil line wherein dirt particles are centrifugally separated from the remainder of the oil and are collected in a sump from which they may be periodically removed.

Mr. Reinsch is section head in the Engineering Department of Moraine Products. Currently, his major project is the investigation of high-strength materials made by powder metallurgy. His previous work in powder metallurgy as applied to filters resulted in three patents. Mr. Reinsch received the B.S. degree in metallurgical engineering from Michigan College of Mining and Technology in 1940.

Grove S. Dow, Jr., Robert N. Falge,* and George W. Onsken, Jr.,* *Guide Lamp Division, Anderson, Indiana, for a Traffic Signal Viewer, No. 2,679,179, issued May 25.* This patent relates to a traffic signal viewer having a concave rear face and a plurality of prisms on the front face, the prism angles being such as to produce an uninterrupted image of objects to the front of and above the horizontal axis of the vehicle.

Mr. Dow is no longer with the Division.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

Film Relates Fundamental Physics and Jet Propulsion

"The ABC of Jet Propulsion" is the latest in a growing series of educational 16-mm, sound motion-picture films available for loan from the General Motors Film Library, Detroit 2, Michigan. This 20-min film, which educators have found valuable as a supplement to their lectures, uses animated techniques in full color to reduce the principles of jet propulsion to the simplest possible terms. In addition to the basic principles, the presentation carries through an explanation of a turbo-jet aircraft, covering all of its essential parts, and follows with a similar treatment of turbo-prop aircraft. Inquiries about booking of this or other films may be directed to:

General Motors Corporation
Department of Public Relations
Film Section
General Motors Building
Detroit 2, Michigan

Recent Speaking Engagements Filled by GM Engineers

High points of the year for engineers in many General Motors locations are the Summer Meeting of the Society of Automotive Engineers, in which a number of GM engineers take an active part, and the annual Conference for Engineering Educators, sponsored by the Engineering and Manufacturing Staffs of the Central Office and co-ordinated by the Educational Relations Section.

A survey of individual participation in these programs is included in the following, which covers most of the appearances of GM technical folks before engineering and other audiences.

During the period from June 1 to July 31, the number of appearances before student groups decreased but many requests have been received by General Motors Divisions for fall appearances.

Engineering educators are reminded that the Educational Relations Section will assist upon request to obtain the services of General Motors engineers to speak before student groups, including classroom presentations.

John A. McDougal, military products engineer in the Engineering Department of AC Spark Plug Division in Flint, Michigan, appeared before the Machine Design Section of the American Society of Mechanical Engineers in Detroit, Michigan, on May 24. The title of his presentation was "The Skysweeper Anti-Aircraft Gun and Its Fire Control."

Two engineers from Aeroproducts Operations of Allison Division lectured at the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics, meeting in Cleveland, Ohio, on June 15.

Gerald Hook, project engineer in the Technical Analysis Department, outlined "The Control Requirements for VTO (Vertical Take-Off) Aircraft."

Francis Conn, experimental engineer in the same Department, discussed "Turbo-Prop Control Requirements."

J. T. Horner, supervisor of the Engine IBM Calculation Group, Engineering Services Department, Allison Division, completed four speaking engagements during the period covered in this report.

On June 24 Mr. Horner discussed "The Use of Engineering Computing Equipment in General Motors" before the Association for Computing Machinery, meeting in Detroit, Michigan.

Before the Association for High School Mathematics Teachers meeting held at Indiana University, Bloomington, on June 30, July 1 and 2, Mr. Horner spoke on "Industrial Problems Which May Be Solved by Computing Machinery," "How the Computor Works," and "The Scope of Computing Machinery."

On June 10, before the National Junior Honor Society at East Syracuse High School, New York, **W. I. Snover,** supervisor of process engineering at Brown-Lipe-Chapin Division, outlined "The Opportunities in Industry Through the Progress of Science and Engineering."

On May 17 **D. DonCarlos,** assistant chief product engineer at the Kansas City plant of B.O.P. Assembly Division, appeared before the Soroptimist Club in Manhattan, Kansas. His talk was entitled "Engineering Plans and Plant Layout—Type and Mission—Dual-Purpose Operations."

Charles A. Chayne, vice president in charge of the General Motors Engineering Staff, addressed a joint meeting of executives from insurance groups and automobile manufacturers in Detroit, Michigan, on June 9. He spoke on "The Aspects of Automobile Engineering that Relate to Vehicle Safety."

On June 22 Mr. Chayne, as chairman of the Engineering Advisory Committee, Automobile Manufacturers Association, addressed the annual joint meeting of the Engineering Committee, American Association of Motor Vehicle Manufacturers, and representatives of the A.M.A. in Detroit. He spoke on the accomplishments and projects of the two committees.

Harry Dumville, director of the New Devices Section of the GM Engineering Staff, addressed the Sports Car Club, meeting in Grosse Pointe, Michigan, on May 13. The title of his talk was "The Chevrolet Corvette."

In connection with the Student Conference of the A.S.M.E. held at Wayne University, Detroit, Michigan, on April 26 and 27, **J. J. Cronin,** vice president in charge of the Manufacturing Staff, presented the talk "Are You Ready for the Adventure Ahead?" during a group trip to the GM Technical Center.

Mr. Cronin also spoke on "The Engineer and Industry" during the Annual Engineering Day sponsored by Marquette University's engineering alumni and held on the University campus, Milwaukee, Wisconsin, on May 1.

Donald H. Johnson, industrial engineer in the Work Standards and Methods Engineering Section of the Manufacturing Staff, presented the paper "Approaching Methods Work Through Participation and Training" during a refresher conference on work simplification and measurement held at the University of Pennsylvania, Philadelphia, on June 25.

Kenneth A. Meade, director of the Educational Relations Section, Central Office Department of Public Relations, spoke to the College English Association, meeting at Michigan State College in East Lansing, Michigan. The title of his talk, given on June 24, was "Industry Looks at a Liberal Arts Education."

On May 18 **Maurice Olley,** director of the Research and Development Section of Chevrolet Motor Division, appeared before the Buffalo, New York Section of the Society of Automotive Engineers. He spoke on "European Car Design and its Influence on American Cars."

At the 1954 Annual Conference of the Society of the Plastics Industry, held in Cleveland, Ohio, on June 10, **John Coffin,** assistant metallurgical engineer in the Production Department of Chevrolet Motor, presented the talk "The Corvette Plastic Body."

"The Graduate Engineer—His Place in the Automobile Industry Today and Tomorrow" was the speech given by **R. D. Amberson,** director of personnel activities at Chevrolet Motor. The talk, given on June 15, was presented to the coordinators of engineering cooperative programs at a meeting of the Cooperative Education Division, American Society for Engineering Education, held at the University of Illinois in Urbana.

On July 13, during the Conference of the American Society of Refrigeration Engineers held in Seattle, Washington, **Robert W. Leland,** section engineer—

hermetic motors, Product Engineering Department of Delco Products Division, participated in a panel on fan motors in air conditioning.

Thomas E. Taylor, administrative engineer at Detroit Diesel Engine Division, outlined "What Problems in Industry Face Our Graduates Today" before the faculty of the University of Illinois, Urbana, on June 14.

H. G. Hokenson, assistant production liaison engineer at Electro-Motive Division, lectured on "The Opportunities for Vocations in the Diesel Engine Field" before vocational classes of Crane Technical High School, Chicago, Illinois, on June 3.

Before the Southeastern Railway Diesel Club, meeting in Jacksonville, Florida, on June 8, **R. B. Wallis,** mechanical design engineer in the Mechanical Section of Electro-Motive, described the "Maintenance of the New C-Type Engine and the Conversion of Present Engines to New C-Type Engines."

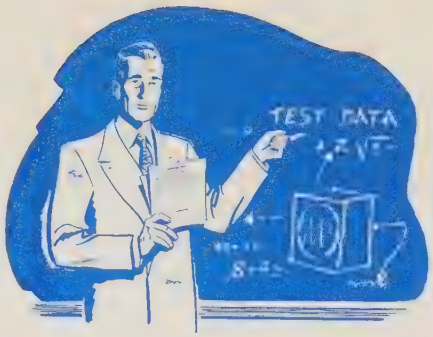
G. F. Roddewig, experimental engineer at GMC Truck and Coach Division, appeared before the American Association of Motor Vehicle Administrators in Detroit on June 23. The title of his talk was "The Exhaust Location on Commercial Vehicles."

On June 29, at the Summer Conference of the Auto-Mechanics Group of the Massachusetts State Vocational Teachers held in Fitchburg, Massachusetts, **Gerald R. Borshar,** field engineer at Guide Lamp Division, described "The Autronic-Eye Automatic Headlamp Control."

On May 7, at a joint meeting of the Buffalo, New York and the Ontario, Canada Sections of the A.S.R.E., the Buffalo Section of the A.S.M.E., and the Buffalo Section of the S.A.E., **J. R. Holmes,** chief engineer at Harrison Radiator Division, lectured on "The Automotive Application of Air Conditioning."

George V. Gerber, project engineer in the Product Engineering Department of Hyatt Bearings Division, spoke at the Mathematics Institute held during Rutgers University's summer session. The topic of the talk, given on July 9, was "Mathematics in Industry."

On May 15 **Ray Burns,** production engineer at Oldsmobile's Jet Plant, appeared before the Central Michigan Chapter of the American Society of Tool



Engineers, meeting at Michigan State College in East Lansing. The title of his presentation was "The Machining of Stainless-Steel Alloys Used in Jet-Engine Blade Manufacture."

John Howe, supervisor of the Production Engineering Department of Oldsmobile's Jet Plant, also spoke at the same A.S.T.E. meeting on May 15. The title of his talk was "The Machining of Jet-Engine Alloys."

Donald C. Perkins, body engineer at Oldsmobile, described "The Oldsmobile Air Conditioning System" to the Dayton, Ohio Chapter of the S.A.E. on May 27.

J. R. Seip, foreman in the Inspection Department of Oldsmobile, addressed the Muskegon, Michigan Section of the American Society for Quality Control on May 27. The title of his talk was "Oldsmobile Obtains More Quality with Fewer Charts."

"Some Aspects of Particle Ignition" was the title of the paper presented before the American Petroleum Institute in Houston, Texas, on May 12. The Research Laboratories Division personnel that presented the talk were **Frederick W. Bowditch,** senior engineer; **George J. Nebel,** research engineer; and **Robert E. Wilson,** senior engineer—all in the Fuels and Lubricants Department.

On May 12, at the same meeting, Mr. Wilson presented a discussion of "The Pre-Ignition Resistance of Fuels."

Russell Donovan, research physicist in the Physics and Instrumentation Department of the Research Laboratories, presented the paper "The Infrared Spectra of the Combustion Stages in the Low-Temperature Combustion of Diethyl" during the Symposium on Molecular Spectroscopy held in Columbus, Ohio, on June 17.

During the Second U. S. National Congress of Applied Mechanics held at University of Michigan, Ann Arbor, from June 14 through 18, **Leonard G. Johnson,** mathematician in the Engineering Mechanics Department of the Research Laboratories, described "The Derivation of the Fundamental Equation of Residual Stress Analysis by Dissection."

"Carburetion—Past, Present, and Future" was the title of the talk given before the Genesee Valley Antique Automobile Club, Rochester, New York, on May 13. The speaker was **Don Stoltman,** project engineer-in-charge of advanced design, Carburetor Development Department of Rochester Products Division.

Mr. Stoltman spoke at the July 9 meeting of the Society of Automotive Testers held in Chicago, Illinois. The title of his talk was "The Relations of Fuels and Engines to Carburetion Operation."

1954 Society of Automotive Engineers' Summer Meeting

The following General Motors engineers participated in the Society of Automotive Engineers' Summer Meeting held in Atlantic City, New Jersey, from June 6 through 11.

John Haviland, senior project engineer in the Experimental and Development Section of Fisher Body Division, was a panel member on a round-table discussion of automotive seating on June 7.

The same day, **L. E. Muller,** staff engineer—acoustics at Buick Motor Division, member of a panel on air conditioning, discussed "The Conventional System with Evaporator Unit in the Trunk Compartment and with Roof Duct Air Distribution." During the same panel discussion, **J. R. Holmes,** chief engineer at Harrison Radiator Division, described the underhood system of air conditioning and **W. J. deBeaubien,** accessory engineer in the Product Engineering Department of Pontiac Motor Division, described "The Pontiac Air Conditioner with Front-End Air Discharge."

At the evening session on June 7, **Kenneth E. Coppock,** assistant chief engineer, Engineering Division, Fisher Body, in conjunction with an engineer from another corporation, presented the paper "Who Is the Designer—the Stylist or the Engineer?"

On June 8 **L. A. Zwicker,** assistant chief engineer, Product Engineering Department, Harrison Radiator, was a panel member of a round-table discussion on car heating and ventilating.

The same day **Von D. Polhemus,** engineer-in-charge of the Structure and Suspension Development Group, GM Engineering Staff, was chairman of the round table on noise suppression in passenger cars and **L. E. Muller,** staff engineer—acoustics, Buick Motor, was a panel member.

L. E. Cummings, assistant manager of material control, Delco Products Division, was a panel member discussing the subject of a manufacturing cost reduction technique from the design board to the shipping room.

M. T. Hayes, assistant to the truck engineer, Truck Department, GMC Truck and Coach Division, participated in a round-table discussion on the performance characteristics desired by the operator, covering acceleration, gradeability, and roadability.

On June 9 **M. J. Diamond,** research engineer at Central Foundry Division, described "The Magnetic and Resistance Methods Used in Non-Destructive Testing."

At the same meeting **E. F. Weller,** assistant head of the Physics and Instrumentation Department, Research Laboratories, outlined "The ABC's of Ultrasonic Inspection."

During the afternoon symposium on new developments in crankcase oils, **J. B. Bidwell,** assistant head of the Mechanical Development Department, and **R. K. Williams,** assistant head of the Fuels and Lubricants Department, both of the Research Laboratories, discussed "New High V. I. Oils in Automotive Engines."

R. P. Atkinson, engine project engineer in the Power Turbine Engineering Department of Allison Division, presented the talk "The Problems of Compressor Air Bleed for Cabin Pressurization."

"Combustion Chambers of Automotive Diesel Engines" was the subject of a round-table discussion of which **John Dickson,** chief design and development engineer at Detroit Diesel Engine Division, was a panel member.

Maurice Olley, director of the Research and Development Section, Chevrolet Motor Division, organized the round table "Comfort in Cabs" of which **M. T. Hayes,** assistant to the truck engineer, Truck Department, GMC Truck and Coach, discussed cab ride.

During the General Session held on June 9, **Ralph A. Richardson,** head of the Administrative Engineering Department, Research Laboratories, served as chairman. His talk "Introduction to Gas Turbine Automotive Vehicles" headed four talks given on the Firebird and the Turbocruiser, gas-turbine vehicles developed by General Motors. **R. F. McLean,** supervisor of special projects in the Styling Section, discussed "An Aerodynamic Design in Plastics—the Design of the Firebird Body;" **Robert Schilling,** head of the Engineering Mechanics Department, Research Laboratories, described "A Cradle for New Power—Chassis Features of the Firebird;" and **W. A. Turunen,** head of the Gas Turbines Department, Research Laboratories, presented a discussion of the question "Pinwheels or Pistons?"

On June 10 **Lloyd Withrow,** head of the Fuels and Lubricants Department, Research Laboratories, was chairman of a symposium on pre-ignition. During the symposium, **J. R. Landis,** supervisor in the same Department, lectured on "The Detection of Abnormal Flame Fronts in Road Tests with an Engine Using Independent Ionization Gaps."

On June 11 **John D. Caplan,** supervisor, and **Robert E. Wilson,** senior engineer, both of the Fuels and Lubricants Department, Research Laboratories, jointly presented the paper "Characteristics of Fuel Pump Operation During Vapor Lock."

1954 General Motors Conference for Engineering Educators

The organization and operation of various activities in General Motors were described by GM Central Office and Divisional speakers at the third Conference for Engineering Educators, sponsored by the Engineering and Manufacturing Staffs of GM. The Conference sessions were held in Detroit, and at other locations as noted below, from June 20 to July 2.

On June 21 **William F. Andersen,** director of the Budget and Procedure Section, spoke on "The Organization and Operations of General Motors." Other speakers during the day included: **Charles A. Chayne,** vice president in charge of the Engineering Staff, who described "Engineering in General Motors;" **John J. Cronin,** vice president in charge of the Manufacturing Staff, who discussed "Manufacturing in General Motors;" **Paul Garrett,** vice president in charge of the Public Relations Staff, spoke on "Public Relations and Technical Education;" **Arthur J. Altz,** assistant chief engineer in charge of Administration at Chevrolet Motor Division, who talked on "Engineers—How They Function;" **Edwin L. Yates,** director of technical employment, Personnel Staff, who described "Technical Personnel Activities;" and **Merle C. Hale,** director of the Salaried Personnel Activity of the Personnel Staff, who spoke on "Manpower Planning and Its Relation to the Utilization of Engineering Graduates."

The agenda for June 26 included a trip to General Motors Institute in Flint, Michigan, where the following persons spoke to the educators: **Guy R. Cowing,** president of G.M.I., described "The Organization and Function of General Motors Institute;" **Harold M. Dent,** administrative chairman of the Cooperative Engineering Program at G.M.I., described the purpose and work of the "Cooperative Engineering Program;" **Harold B. Baker,** administrative chairman, Cooperative Business Administration Program and chairman, Organization and Management Department, discussed "The Relation of the Cooperative Business Administration Program to Engineering;" **Charles L. Tutt, Jr.,** administrative chairman of the Fifth-Year and Thesis Programs, described his activity; and **Charles J. Sahrbeck, Jr.,** administrative chairman, Plant Management Training and chairman, Program Research and Development, outlined "Program Development."

On June 28, during a field trip to the GM Proving Ground at Milford, Michigan, **H. H. Barnes,** director of the Proving Ground, outlined "The Organization and Function of the General Motors Proving Ground."

At the dinner held on June 29 at the Park-Shelton Hotel, the educators heard remarks by **Charles F. Kettering** on the engineer and his education. Later the group was addressed by **Harlow H. Curtice,** president of General Motors.

A Typical Problem in Automotive Design:

Determine the Length of the Governor Valve in the Hydra-Matic Automatic Transmission

By GEORGE R. SMITH
General Motors
Engineering Staff

Valve length: a function of outward centrifugal force

There are two conditions which determine the exact time that a gear-ratio shift should be made in an automatic transmission—throttle opening and car speed. A shift-control valve translates the conditions of throttle opening and car speed into hydraulic pressure which, in the Hydra-Matic automatic transmission, is then directed to planetary-gear units. The shift-control valve receives data pertaining to car speed from a governor assembly which is geared to the output shaft. The governor assembly contains two valves which make use of the centrifugal force of a spinning mass as a measure of car speed. An inward hydraulic pressure is present which balances the outward centrifugal force. The problem is to determine the length of one of the governor valves necessary to produce a predetermined curve of governor pressure versus car speed. The solution to the problem will appear in the November-December 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

THE purpose of an automotive transmission is to provide suitable gear ratios between the engine and the rear wheels for all driving conditions or, stated in another manner, to vary the speed and torque of the rear axle in relation to the speed and torque of the engine. The transmission section of the Hydra-Matic is composed of three planetary-gear units which provide suitable gear ratios to give four forward speeds and one reverse speed.

In order for the Hydra-Matic transmission to be automatic, that is, change the various gear ratios provided by the planetary-gear units without any conscious effort on the part of the driver, an involved hydraulic control system is used to accomplish the automatic shifting of gear ratios. To obtain the correct gear ratio from the planetary-gear units, hydraulically operated brake bands and friction clutches are used to couple the proper gear members of each planetary unit. The brake bands and friction clutches are automatically actuated by a mechanism which constitutes the heart of the hydraulic control system—the shift-control-valve body.

There are two conditions which determine the exact time when a gear-ratio shift is to be made—car speed and throttle opening. It is the function of the shift-control-valve body to translate the infinite number of conditions of car speed and throttle opening into hydraulic pressure. This hydraulic pressure is then directed to the transmission which shifts automatically to the proper gear ratio at the correct time through the application of the brake bands and friction clutches.

The arrangement of the shift-control-valve body in the hydraulic control system is such that it is not directly sensitive to car speed and throttle opening. It is necessary, therefore, that two other mechanisms be used which will directly transmit to the shift-control valve the instantaneous throttle opening and car speed. A mechanical linkage from the accelerator pedal to the shift-

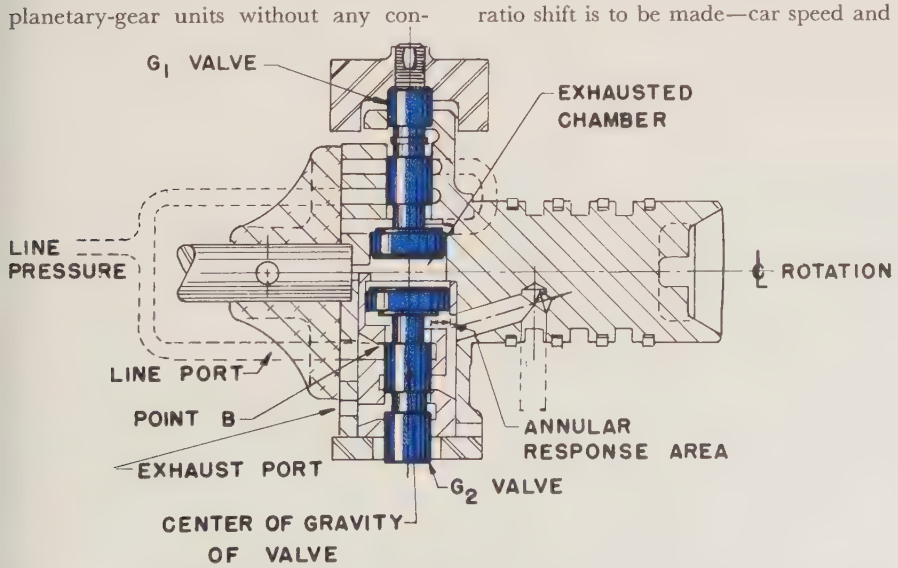


Fig. 1—Section drawing of the Hydra-Matic automatic-transmission governor assembly. Two governor valves, G_1 and G_2, are necessary to insure that all shift points for light-throttle and full-throttle operation will be possible.

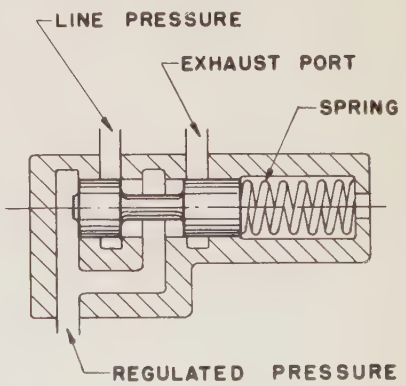


Fig. 2—Each governor valve operates in a manner similar to the above hydraulically balanced valve. In this type of valve, a force is created on the end of the valve by oil pressure flowing through the valve's passages. When this force exceeds the spring force, the valve will move against the spring and close the line port. The governor valve substitutes a variable centrifugal force for the spring force of the hydraulically balanced valve.

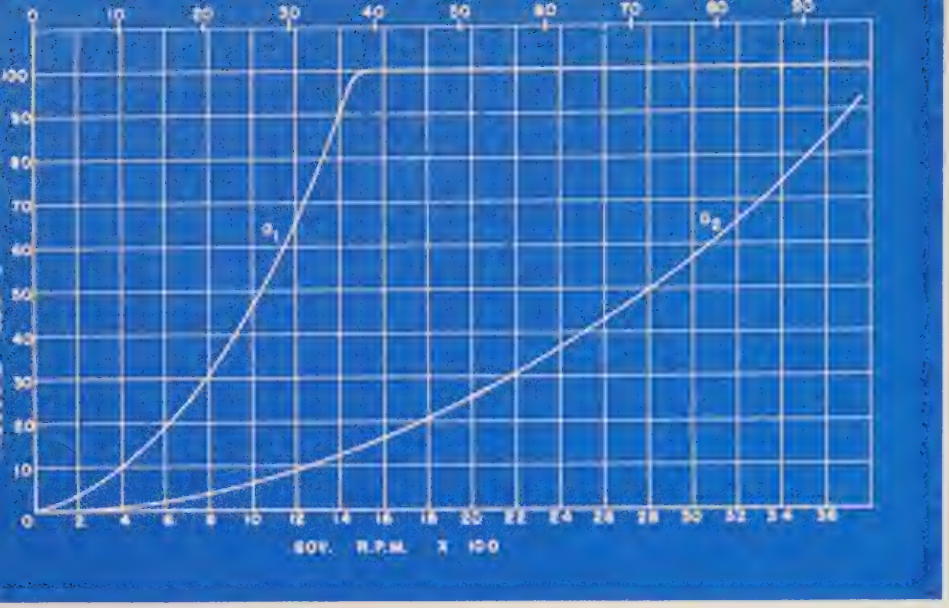


Fig. 3—Regulated pressure rise of governor valves G_1 and G_2 with increase in car speed.

control-valve body transmits throttle opening information, and a governor, geared to the output shaft, transmits car-speed information. The mechanical-linkage arrangement and the governor, therefore, working in conjunction with the shift-control valve, permit the transmission to shift from low gear to high gear hydraulically and automatically, according to accelerator-pedal position and car speed.

The Hydra-Matic automatic-transmission governor makes use of the centrifugal force of a spinning mass as a measure of car speed. The governor is directly driven by the output shaft and delivers hydraulic pressure, varying with car speed, to the shift-control valve. The upshift movement of the shift-control valve is opposed by a spring force plus throttle pressure, which varies directly as the accelerator pedal is depressed. As car speed increases, a point is reached where the hydraulic pressure through the governor is sufficient automatically to open the shift-control valve against the opposing forces. Hydraulic pressure is then transmitted to the brake bands and friction clutches.

Fig. 1 shows a section drawing of the Hydra-Matic automatic-transmission governor assembly. There are two extremes of shift points which the automatic transmission must satisfy—light-throttle operation and full-throttle operation. Because of this variation, therefore, it is necessary to have two governor valves, G_1 and G_2, to insure that all shift points will be foolproof. When the governor assembly starts to rotate, G_1 pressure builds up directly as the centrifugal force of the valve. When the governor-assembly rotation reaches approximately 1,500 rpm the centrifugal force that is built up due to the rotation exceeds the maximum balanced pressure and the G_1 valve moves out and allows full-line pressure to flow to the shift-control valve. The same procedure takes place for the G_2 valve, except that the centrifugal force rises at a slower rate than is necessary for the G_1 valve.

Each governor valve operates very much like a hydraulically balanced valve, an example of which is shown in Fig. 2. In a hydraulically balanced valve, oil flows through its passages until the oil pressure creates a force on the end of the valve. When this force exceeds the spring force the valve moves against the spring and closes the line port. The valve, therefore, balances a hydraulic force against the spring force. The pressure regulated is equal to the spring force divided by the area of the valve exposed to the pressure.

The hydraulic governor valve substitutes a centrifugal force for the spring force of the hydraulically balanced valve—a variable centrifugal force proportional to the square of the car speed—and, therefore, produces a pressure in the image of the square of the car speed. The pressure of the line port that feeds each governor valve must exceed the governor value to be regulated. The governor line pressure of the Hydra-Matic automatic transmission is 100 psi.

It is necessary that the governor pressure continue to rise past the last shift point and that the pressure rise, per mile per hour, be relatively high. The last shift point for the Hydra-Matic automatic transmission takes place at 75 mph. Fig. 3 shows the regulated pressure rise of the G_2 governor valve with increase in car speed. It is this valve which supplies the pressure rise for the above condition.

To have a satisfactory force balance on the shift-control valve at low car-speed operation, the governor pressure must increase rapidly. This rapid increase in pressure with increase in car speed is supplied by governor valve G_1 for shift points at low car speed and by governor valve G_2 for shift points at high car speed (Fig. 3). By the use of the G_1 and G_2 regulated pressure curves therefore, it is possible to transmit any number of hydraulic-pressure combinations to the

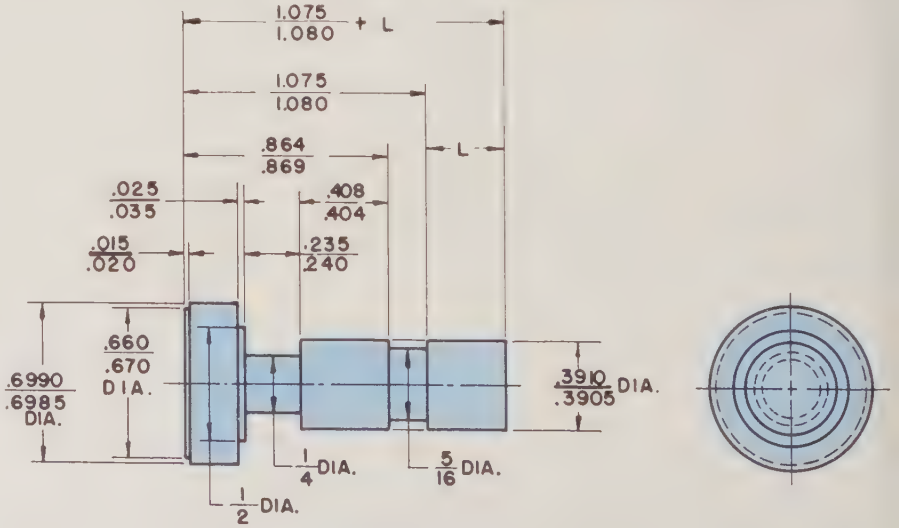


Fig. 4—Detailed drawing of the G_2 governor valve of the Hydra-Matic automatic transmission.

shift-control valve to obtain a desired shift pattern.

The relation of the G_2 governor valve to the ports is such that the line port is always closed before the exhaust port is opened. This relationship is possible by having the valve overlap both the exhaust port and line port, thus assuring minimum leakage from line pressure. The average total overlap for the G_2 valve in the valve body is approximately 0.020 in. The movement required for regulation, therefore, is quite small.

For the purpose of this problem, assume that valve regulation is established at the position shown in Fig. 1. In actual operation, regulation will occur at a point somewhere between this position and the exhaust-port open position.

Problem

The problem is to find dimension L of the secondary governor valve G_2, shown detailed in Fig. 4 and, therefore, the total length of the G_2 valve necessary to produce the G_2 curve of Fig. 3. In solving for L, friction can be ignored and the mean of all dimensions in Fig. 4 used. The valve is of steel, which can be considered to have a weight of 0.281 lb per cu in. Point B in Fig. 1 is 0.560 in. from the centerline of governor rotation. As stated previously, the governor line pressure for the Hydra-Matic automatic transmission is 100 psi.

The G_2 governor-valve length can be determined at any car speed and it will be correct for all car speeds. This is because both the G_2 curve and the centrifugal force of the valve vary as the square of the speed. It should be mentioned, however, that the solution which will appear in the November-December 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL will be based on a car speed of 3,200 rpm.

Information which will prove helpful in solving the problem is that it will be required first to determine the center of gravity and weight of all the G_2 governor-valve cylindrical sections. This will then make it possible to compute the summation of the known individual centrifugal forces. The difference between the summation of these centrifugal forces and the hydraulic inward force equals the force to be produced by the end section of the G_2 governor valve. This will result in a basic equation from which the solution to the problem can be carried to completion.

Solution to the Previous Problem:

Determine the Amount of Alloy or Inoculant Required for Specified Properties of Cupola Iron

By LEONARD W. CZARNECKI
Cadillac Motor
Car Division

A quick calculation puts the right iron in the casting

Adding materials to molten iron in the ladle before pouring is an operation performed every day in a gray-iron foundry producing for automotive requirements. Because the composition of the base iron may vary from day to day, according to the nature of the cupola operation and the nature of the metal charge, the amounts of the alloys and inoculants to be added must be re-determined frequently in order for the iron to meet specifications. The foundry engineer uses a simple, practical method of calculating these amounts. This is the solution to the problem presented in the July-August 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL. The amounts of material required in the four cases described are: 5 lb of ferrochrome, 3.75 lb of V-5 Alloy, 2.1 lb of ferrosilicon, and 3 lb of SMZ Alloy.

GRAY-IRON castings for automotive use are produced to give certain important properties in the resulting part or component. Such properties are ease of machining, compressive strength, resistance to heat shock, tensile strength, and hardness, and all of these are affected by the graphite content of the iron. The control of the graphite content, in turn, is affected by the presence of certain elements in the iron.

To achieve the desired properties in the castings, therefore, these elements must be present in definite amounts falling within a specified range of values. A typical casting, for example, might require a chemical analysis of 3.30-per cent to 3.35-per cent total carbon, 2.10-per cent to 2.20-per cent silicon, 0.80-per cent maximum manganese, and 0.20-per cent maximum sulphur.

Throughout the manufacturing process, there are a number of ways of compensating for deviations from these values in the iron. One important way is the control in the foundry of the composition of the iron. This type of control is achieved by adding certain alloys and inoculants to the ladle following the discharge of the iron from the cupola (Fig. 1). Thus, a continuing problem for the foundry engineer is the correct addition of materials to the iron to give

Fig. 1—Inoculants or alloys are added in small amounts to the crane ladle after the iron is received from the cupola. The crane ladle transfers the molten iron from the cupola to the pouring ladles at various locations in the foundry.

AVAILABLE ALLOYS AND INOCULANTS

Alloy		Per Cent of Alloy Available	Form	Per Cent of Recovery in Ladle
Ferrochrome			20 mesh	85
	Cr	67-70		
	Si	1-2		
V-5 Alloy			20 mesh	85
	Cr	38-42		
	Si	17-19		
	Mn	8-11		
Ferrosilicon			⅜ in. to 12 mesh	95
	Si	83-88		
SMZ Alloy			¼ in. to 32 mesh	95
	Si	60-65		
	Mn	5-7		
	Zr	5-7		

Table I—Composition of available alloys and inoculants used to change the properties of gray iron.

it the specified properties before it reaches the succeeding stages of manufacture.

The charging materials and the daily cupola operation may cause periodic variations in the base iron. The composition is checked frequently by *chill tests* and by *chemistry checks*. The chill test, which is a visual test, shows whether the carbon and silicon contents are dropping or climbing. This is determined largely by experience in the particular foundry. The chemistry check is made to verify the amounts of all elements present.

In this problem, as presented in the July-August 1954 issue, the base iron was found to have certain properties, namely: a residual chromium content of 0.10 per cent, a silicon content of 2.17 per cent, a 163 average Brinell hardness number *Bhn* on a machined surface using a 3,000-kg load, and a tensile strength of 30,000 psi.

The properties of the iron are to be changed by alloying and inoculating with available materials having the compositions listed in Table I.

In the first two typical cases described in the problem, alloying elements are to be added to achieve (a) a chromium content of from 0.25-per cent to 0.30-per cent, 197 Bhn to 207 Bhn, 35,000-psi minimum tensile strength, and (b) 0.15-per cent to 0.20-per cent chromium content, 179 Bhn to 187 Bhn, and 35,000 psi minimum tensile strength. This alloying results in an increase of the Brinell hardness number and the tensile strength as well as a stabilization of the graphite.

For practical use, the foundry engineer desires to know what per cent increase in chromium content of the iron can be expected per pound of alloy added to the ladle. This is determined from the following calculation for case (a):

$$\%\ \text{Cr per lb of alloy} = \frac{(1\ \text{lb alloy})\ (100)}{\text{weight of iron in ladle, lb}} \times (\text{Cr in alloy, \%})\ (\text{recovery in ladle, \%}).$$

Thus,

$$\%\ \text{Cr per lb FeCr} = \frac{(1)\ (100)}{1{,}700}\ (0.70)\ (0.85) = 0.035\%.$$

The base-iron chromium content must be increased from 0.10 per cent to a mean figure of 0.275 per cent, or an increase of 0.175 per cent. Thus, to obtain 0.175 per cent more chromium, the following calculation is made:

$$\frac{1}{0.035} = \frac{X}{0.175}$$

$$X = \frac{0.175}{0.035}$$

= 5 lb of ferrochrome required in the ladle.

For case (b) an increase in chromium of 0.075 per cent is required using an alloy known commercially as V-5 Alloy. Similarly, the per cent increase per pound of V-5 Alloy is determined, after which the amount of V-5 added to the ladle is calculated as follows:

$$\%\ \text{Cr per lb V-5 Alloy} = \frac{(1)\ (100)}{1{,}700}\ (0.40)\ (0.85) = 0.02\%.$$

To obtain 0.075 per cent more chromium:

$$\frac{1}{0.02} = \frac{X}{0.075}$$

X = 3.75 lb of V-5 Alloy required in the ladle.

As the above cases demonstrate, once the amount of increase per pound of a given alloy is known, any required increase in the ladle can be determined simply and quickly.

The third and fourth cases described in this problem are examples of the addition of inoculating materials. The inoculation process promotes graphitization of the iron. Thus, in case (c) the silicon content must be increased from 2.17 per cent to a value between 2.24 per cent and 2.29 per cent. The calculations for the addition of ferrosilicon are:

$$\%\ \text{Si per lb of inoculant} = \frac{(1)\ (100)}{1{,}700}\ (0.85)\ (0.95) = 0.048\%.$$

To obtain 0.10 per cent more silicon:

$$\frac{1}{0.048} = \frac{X}{0.10}$$

= 2.1 lb of ferrosilicon required in the ladle.

In the fourth case (d) a different inoculant containing silicon, manganese, and zirconium, is used to achieve the same increase in silicon as (c) while acquiring the effects of the other elements in this material, known commercially as SMZ Alloy. The calculations are:

$$\%\ \text{Si per lb of inoculant} = \frac{(1)\ (100)}{1{,}700}\ (0.60)\ (0.95) = 0.034\%.$$

To obtain 0.10 per cent more silicon:

$$\frac{1}{0.034} = \frac{X}{0.10}$$

= 3 lb SMZ Alloy required in the ladle.

Engineering Educators—

Comments are invited from engineering educators on the appropriateness for classroom use of the series of problems being presented by engineers in the GENERAL MOTORS ENGINEERING JOURNAL. Communications may be directed to the editor.

Contributors to Sept.-Oct. 1954 Issue of

GENERAL MOTORS Engineering JOURNAL

ROBERT B. COLTEN,

contributor of "A Case Study: Applying Industrial Electronics to Thickness Measurement of Non-Ferrous Strip," is senior project engineer in charge of the Electronics Department of the General Motors Process Development Section. He joined this organization in 1947 after a year at Michigan State College where he held a teaching fellowship in physics while completing work on a master's degree.

Mr. Colten received the B. S. degree from the University of Michigan in 1939. He helped finance his education by working part-time and summers in a radio factory, telegraph office, and radio-repair shop. In 1939 and 1940 he took graduate courses at Michigan State College.

His experience prior to joining General Motors included three years of geophysical exploration work and the development of new seismograph equipment for Texaco Development Corporation and Keystone Exploration Company. During World War II he tested machinery and equipment on naval and merchant ships at the Pennsylvania Shipyards in Beaumont, Texas. He also sailed as chief electrician and as engineer on electric-drive merchant ships, and later taught electrical engineering at the United States Merchant Marine Academy, Kings Point, New York.

Mr. Colten's technical affiliations include membership in the American Physical Society and the physics fraternity, Sigma Pi Sigma.

LEONARD W. CZARNECKI,

contributor of "A Typical Problem in Foundry Operation: Determine the Amount of Alloy or Inoculant Required for Specified Properties of Cupola Iron" for the July-August issue and the solution for this issue, is foreman of the Maintenance Department in the Foundry at Cadillac Motor Car Division, Detroit, Michigan. He supervises maintenance of equipment and facilities for the entire Foundry. He was advanced to this post on June 1, 1954 after serving as foreman of Melting Operations.

The problem and its solution presented by Mr. Czarnecki are typical of the situations which are faced daily in gray-iron cupola operation. Often, the foundry engineer must determine the amounts of alloys or inoculants that must be added to iron to effect the desired chemical and physical properties in the iron.

Mr. Czarnecki began his career with General Motors in 1941 when he was sponsored by Cadillac Motor Car as a cooperative student at General Motors Institute in Flint, Michigan. His education at G.M.I. was interrupted by military service with the U. S. Army from 1943 to 1946.

Three years later Mr. Czarnecki was granted the Bachelor of Industrial Engineering degree from G.M.I. As part of his work leading to his degree he wrote a thesis concerning cupola combustion and melting, based on his co-op work at Cadillac Motor Car.

Mr. Czarnecki's technical affiliations include membership in the American Foundrymen's Society.

JOSEPH F. FLETCHER,

co-contributor of "The Dilution Method for Industrial Waste Disposal," is a civil engineer who has made engineering contributions to the armed forces, the State of Ohio, and to industry. He has been in his specialty—heating, ventilating and air conditioning work—with Frigidaire Division, Dayton, Ohio, since 1939 and was responsible for the heating, ventilating and air conditioning tasks in connection with completion of Frigidaire's Plant 3.

Mr. Fletcher's work at Frigidaire was interrupted from July 1941 to February 1946 by service in the U. S. Army Corps of Engineers. He earned a meritorious service award while commanding an aviation engineer battalion in India and Burma and was separated with the rank of major.

Prior to joining General Motors, Mr. Fletcher was an assistant project engineer for the Ohio Department of Highways. His engineering education was in civil engineering at the University of Dayton, where he was graduated in 1937.

Mr. Fletcher is a member of the American Society of Civil Engineers. Although his major work has been in heating, ventilating and air conditioning, he has contributed to other projects at Frigidaire, among them industrial waste disposal projects—the subject of the current paper.

HOWARD M. GEYER,

co-contributor of "How a Comparative Weight Analysis of Aircraft Actuators Aids Designers in Choosing the Most Efficient Type," serves as chief product research engineer at Aero-products Operations of Allison Division at Dayton, Ohio. His entire career has been spent at this Division which he joined in August 1940 as junior draftsman. He advanced steadily from that time through the posts of designer, senior designer, and senior project engineer until he assumed his

present position. Just prior to his employment with General Motors, he was granted the Bachelor of Science degree in industrial engineering from the University of Alabama.

During Mr. Geyer's 14 years with Aeroproducts, he has worked on many and varied projects, some of which are the development of high-pressure pumps, variable engine-cooling fans, propeller de-icing systems, dual rotation propellers, propeller controls, washing machine pumps and accumulators, and electric and hydraulic actuators. A current major project is the development of closed-loop servo-type hydraulic actuators for controlling both the inlet guide vanes and the tail pipe opening of a jet engine afterburner. Eighteen patents have been granted as a result of Mr. Geyer's work and several others, principally in the field of actuators, are pending. The paper appearing in this issue of the GENERAL MOTORS ENGINEERING JOURNAL is adapted from a previous paper co-authored by Messrs. Treseder and Geyer and presented before the American Institute of Electrical Engineers in 1952.

RUDOLPH J. GORSKY,

contributor of "Operating Principles of Buick's Twin-Turbine Dynaflow Torque Converter," serves as staff engineer of the Transmission Department of Buick Motor Division, Flint, Michigan. In this capacity, he is engaged in the design, development, and testing of the 1955 Buick Twin-Turbine Dynaflow Transmission.

Mr. Gorsky's engineering career has been spent entirely with Buick Motor. Originally employed in 1931, he attended General Motors Institute as a cooperative student sponsored by Buick. After graduating from G.M.I. in 1935, where he was a member of the Alpha Tau Iota honorary engineering society, he entered into a graduate engineer training program. During World War II Mr. Gorsky served as Buick resident engineer at Pratt and Whitney Aircraft Division of the United Aircraft Corporation, East Hartford, Connecticut. He returned to Flint in 1945 and became senior transmission design engineer. In 1950 he was promoted to assistant staff engineer of the Transmission Department and in the following year assumed his present position. Mr. Gorsky has been connected with the Dynaflow transmission from its early development stages and his work as a transmission engineer has resulted in the granting of one patent.

Mr. Gorsky's technical affiliations include membership in the Society of Automotive Engineers. He also serves on the Automatic Transmission Fluids Committee, Dryseal Pipe Thread Subcommittee, and Splines, Gears, and Serrations Subcommittee of General Motors. His GENERAL MOTORS ENGINEERING JOURNAL paper is adapted from a paper on the same subject presented in January 1954 before the Dayton, Ohio Section of S.A.E.

ALFRED S. GREIF,

co-contributor of "The Body Draftsman's Function—to Design for Mass Production," serves Fisher Body Division as chief draftsman in the Product Engineering Department. He is responsible for product design and drafting for the Division.

Employed 27 years ago by the Ternstedt Manufacturing Company (now Ternstedt Division) as a tracer, Mr. Greif advanced to designer and, in 1940, was made standards engineer. As a designer he was instrumental in the design of automotive CV's (controlled ventilation), regulators, locks, and seat adjusters. Three patents have been granted as a result of his work on regulators and control ventilator locks.

In 1941 Mr. Greif moved to Fisher Body Division as senior project engineer. During World War II he was made chief engineer of the Artillery Carriage Section and in this capacity had charge of engineering the 90 mm anti-aircraft gun, the 5-in. 38-caliber Navy gun, and also designed a special 90-mm anti-aircraft gun for defense of the Panama Canal. In 1945, when Fisher Body returned to peacetime production, he became assistant chief draftsman and six years later assumed his present post.

Mr. Greif earned the bachelor's degree in mechanical engineering at the University of Detroit in 1931. He is a member of the Society of Automotive Engineers.

HUBERT S. KLINE,

co-contributor of "The Dilution Method for Industrial Waste Disposal," serves Frigidaire Division at Dayton, Ohio, as director of industrial hygiene and sanitary engineering in the Medical Department.

Mr. Kline joined this Division in 1941 as an industrial hygiene engineer. His job responsibilities now include supervision of the industrial waste program and industrial hygiene for all Frigidaire plants.

In addition to the B. S. degree in chemical engineering, earned at the University of Dayton in 1932, Mr. Kline has also done post-graduate work in bacteriology at Ohio State University. Prior to his GM employment, Mr. Kline was chief chemist with the Department of Water for the City of Dayton, where he was in charge of the water and sewage plant laboratory.

Mr. Kline is an active participant in technical society work, having served in many offices, given numerous technical talks, and having published many articles in his field. He represents Frigidaire in a number of other organizations, including the Industrial Water Committee of the Ohio Manufacturers Association, the Industrial Hygiene Foundation (Mellon Institute), the Dayton Water Conservation Committee, and the Governor's Advisory Committee on Ohio Water Resources. He is one of the original members of the GM Waste Control Committee and was chosen vice-chairman for 1953-1954. He is the GM representative on the Metal-Finishing Indus-

A Note on Contributors

Every General Motors engineer is a potential contributor to the GENERAL MOTORS ENGINEERING JOURNAL. Each author seeks to show how fundamental knowledge is applied and adapted to solve industry's technical problems.

try Action Committee of the Ohio River Valley Water Sanitation Commission where he serves as chairman of the subcommittee on treatment methods. Mr. Kline is a member of the National Society of Professional Engineers.

DR. HUGO K. LEBER,

contributor of "A New Machine for Endurance Tests with Stress Cycles of Variable Amplitudes," is manager of the Adam Opel A. G. Engineering Department Chemical and Metallurgical Research Laboratories. The Adam Opel A. G. plant, located in Russelsheim/Main American Zone, Germany, is a General Motors Overseas Division which manufactures Opel cars, trucks, and spare parts, Frigidaire household and commercial cabinets and accessories, and compressor and condensing units and components.

Dr. Leber joined Adam Opel A.G. in 1926 as chief metallurgist after serving as first assistant at the Material Testing Institute of the Technical University at Darmstadt, Germany, where he was granted the Dipl. Ing. degree in 1920 and the Dr. Ing. degree in 1925. Dr. Leber was made Inspection Department Laboratory head in 1929 and two years later assumed his present position.

As manager of the Engineering Department Chemical and Metallurgical Research Laboratories, Dr. Leber is in charge of handling material problems for all operating departments of the Adam Opel plant. His work includes the development of devices and methods relating to such problems in the metallurgical field as induction hardening and gas carburizing and to the development of testing procedures relating to the service life of automotive component parts. His latest accomplishment in this latter field is the development of the special testing machine of which he writes.

Dr. Leber's work has resulted in the granting of a patent relating to a seal for rotating shafts and to the publication of various papers dealing with his vast experience in the field of metallurgy. His technical affiliations include membership in the VDI (Association of German Engineers).

DR. JAMES A. NORTON,

contributor of "Applying Radiochemistry tc the Manufacture of Oil-Filter Elements," serves as senior experimental chemist in the Research Department of AC Spark Plug Division, Flint, Michigan. He originally joined this Division in 1950 as a research chemist assigned to the oil-filter element improvement research program. In addition to the research work connected with this program, Dr. Norton also engaged in work pertaining to hydraulic-press oil maintenance and specific areas of spark-plug ceramics. He assumed his present position in 1951.

Dr. Norton received the Associate in Science degree from Flint Junior College in 1934. Two years later he was granted the S.B. degree from the University of Chicago. Dr. Norton completed graduate work at this University in 1939, when he received the Ph.D. degree in organic chemistry.

Upon completion of his studies, Dr. Norton joined the E. I. du Pont de Nemours and Company, Niagara Falls, New York, where he was employed in the Electrochemicals Department. His work there was concerned with organic chlorine compounds, nylon intermediates, and the mechanism of polymerization. He left this organization in 1943 to become an associate professor of organic chemistry at the University of Colorado, where he continued teaching until 1944 when he became associated with Sharples Chemicals, Inc., Wyandotte, Michigan. At Sharples, where he remained until joining AC Spark Plug, Dr. Norton was primarily concerned with the synthetic chemistry of non-ionic surfactants.

Dr. Norton is a frequent contributor to the technical literature. The gas-flow windowless counter referred to in his current paper is described in detail in the December 1953 *Nucleonics*. He also has had papers published in the *Journal of Organic Chemistry*, *Journal of the American Chemical Society*, and *Chemical Reviews*.

His technical affiliations include membership in the American Society of Lubrication Engineers and past membership in the American Chemical Society and in the American Association for the Advancement of Science. Dr. Norton is also affiliated with Sigma Xi, honorary society for scientific research, and with Phi Delta Chi, chemical and pharmaceutical fraternity.

WILLIAM J. PURCHAS, JR.,

contributor of "The Engineering Organization and Facilities of a General Motors Division," is chief engineer of Diesel Equipment Division, Grand Rapids, Michigan.

The Detroit Institute of Technology granted Mr. Purchas the B.S. degree in mechanical engineering in 1933. Three years later he joined General Motors as a dynamometer operator at the Research Laboratories Division. In late 1936 he moved to the Drafting Department where he was engaged primarily in injection design.

Two years later Mr. Purchas transferred to the Detroit Diesel Engine Division as project engineer on fuel injection. In 1945 he became a senior engineer at the Diesel Equipment Division, his present location, during which period he was concerned with developmental work on fuel injectors and jet nozzles. In addition to this work, he has done developmental work on hydraulic valve lifters. In 1949 Mr. Purchas was promoted to chief engineer.

Before transferring to Diesel Equipment, Mr. Purchas served as assistant resident engineer on marine and industrial applications for a two-year period with a Detroit automotive firm.

Mr. Purchas' work has resulted in three patents in the field of fuel-injector and jet-nozzle design.

He is a member of both the Society of Automotive Engineers and the Engineering Society of Detroit.

JOE M. RIEDEL,

contributor of "Resonant and Transient Theory Applied to Control Power in Demagnetizing" is a research engineer in the Engineering Department, New Departure Division, Bristol, Connecticut, where his recent work has centered on calibration of vibration pickups of

equipment for measuring bearing noise and development of ball-bearing demagnetizers.

Mr. Riedel received his degree in physics in February 1951 from the University of Connecticut, which he attended after serving seven years in the Air Force. His military tasks were principally in communications and electronics, including operational radar countermeasures work. He was promoted through the ranks and was a first lieutenant upon his separation in November 1947.

While attending the University of Connecticut, he taught part-time at the Ward School of Electronics, Division of Hillyer College, in Hartford, and remained there full-time for seven months after earning his degree. He then moved to research and development work with a Hartford company and gained experience on dictation machines, audio amplifiers, and specialized disc recording equipment.

Mr. Riedel became a GM engineer at Bristol in October 1952. His current vibration pick-up work is related to his earlier experience with audio work. He is a member of the Audio Engineering Society.

FRANCIS E. SMITH,

co-contributor of "The Body Draftsman's Function—to Design for Mass Production," serves as senior staff assistant to the chief draftsman in the Design and Drafting Section of Fisher Body Division's Engineering Department.

Mr. Smith started with Fisher Body in 1932 as an engineering clerk in the Ternstedt Engineering Department. He was promoted successively to chief engineering clerk, assistant supervisor of standards engineering and, during World War II, to engineer-in-charge of the B-25 and B-29 projects at Ternstedt, which produced structural forgings and castings for both aircraft types. During the reconversion period he became assistant-in-charge of Ternstedt's Mechanical Engineering Department.

In 1946 Mr. Smith came to Fisher Body Engineering and assumed charge of hydraulic projects, which led to design responsibility for controls for convertible and hardtop bodies. In 1949 he became assistant engineer-in-charge of tank engineering at Fisher's Grand Blanc, Michigan location. There he was instrumental in the design of the concentric recoil mechanism for 90-mm guns on M48 tanks. He returned in 1951 to Fisher Body Central Engineering and in 1953 became senior staff assistant to the chief draftsman, his present position.

Mr. Smith worked for two years as a machinist following his being graduated in 1930 with the B.S. degree in business administration from University of Detroit. Since then he has completed night school engineering courses. He is a member of the Society of Automotive Engineers.

ROBERT C. TRESEDER,

co-contributor of "How a Comparative Weight Analysis of Aircraft Actuators Aids Designers in Choosing the Most Efficient Type," is chief engineer at Aeroproducts Operations of Allison Division at Dayton, Ohio. At the present time, Mr. Treseder is directing design work on propellers for gas turbines and actuators for aircraft control surfaces. Among the projects on which he has been engaged in the past was work on turbo-propeller controls.

Mr. Treseder joined the organization in Dayton in 1946 as a senior engineer. He also held the positions of chief design engineer and assistant chief engineer before receiving his present assignment. Employment prior to coming to General Motors was with the American Telegraph and Telephone Company and the Civilian Engineer Army Air Forces. His electrical engineering degree was received from the University of Utah in 1937.

In addition to having three patents granted as a result of his work with propeller speed controllers, electronic synchronizers, and solenoid valve construction, Mr. Treseder has had several papers published on various subjects relating to propellers.

Mr. Treseder is an active member of the American Institute of Electrical Engineers and the National Advisory Committee for Aeronautics. In the latter organization, he serves on the Subcommittee on Power Plant Controls. He is also a member of the Power Plant Control Subcommittee of the Aircraft Industries Association.

WILLARD F. WAGNER,

contributor of "A Commentary on the Technical Boundaries Within Which the Patent System Functions" and coordinator of this issue's "Notes About Inventions and Inventors," serves as a patent attorney in the Central Office Patent Section, Detroit, Michigan.

Mr. Wagner joined General Motors while engaged in his studies at Wayne University Law School in Detroit. He worked as a machinist on the night shift at Cadillac Motor Car Division, starting in June 1950, and attended daytime classes at Wayne. In January 1951 he transferred to the Central Office Patent Section and completed law studies in night school, receiving the L.L.B. degree in 1953.

Prior to joining General Motors, Mr. Wagner attended Michigan State College and Wayne University, majoring in chemistry. During this time he also acquired additional industrial experience with Vickers, Incorporated, Detroit, Michigan, and Heiland Research Corporation, Denver, Colorado.

In his capacity as patent attorney, Mr. Wagner is concerned with preparing patent applications for inventions developed by General Motors employes and with conducting patent infringement and validity investigations. He is primarily concerned with patent problems involving vehicle suspension systems and off-the-road machinery.

Mr. Wagner joined the Army Air Force in 1942 and served in the European Theater of Operations as a heavy-bombardment pilot. He was separated with the rank of captain.

He is a registered patent attorney and a member of the Michigan Bar.

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

PLASTIC-BLADED NOZZLE

The torque converter of an automatic transmission utilizes a complex arrangement of turbine blades and hydraulic principles to multiply engine torque. The efficiency of the torque converter depends to a great extent upon the shape and angle of the converter blades. To study the effect that various blade shapes and angles have on fluid-flow characteristics, the Transmission Development Group of the General Motors Engineering Staff has developed a device which enables a visual analysis to be made of turbine blades under actual flow conditions. By the use of high-velocity water flowing through a plastic-bladed nozzle, transmission engineers can make visual checks through the transparent nozzle and also take high-speed pictures for a detailed analysis.

GENERAL MOTORS

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